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Lulejian & Associates, Inc.
5205 Leesburg Pike
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This report covers the data base compilation phase and statistical analysis phase of an effort to reexamine the structural damage to buildings at Hiroshima and Nagasaki and at the Nevada and Pacific Test Sites. The primary emphasis in the efforts was to establish whether collateral damage versus intended damage oriented considerations affected the estimation of the key parameters of the probability of damage versus distance to the ground zero relationships.

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NOMENCLATURE

R_{50}	-	Distance from the ground zero at which the probability of damage is 0.5
P_{50}	-	Calculated peak pressure at which the probability of damage is 0.5
$P_d(R)$	-	Probability of damage versus distance to the ground zero relationship
σ_d	-	Distance-damage sigma. Related to variance of probability of damage versus distance to the ground zero relationship
β	-	Standard deviation of log normal distribution function
a	-	"Cut-off" limit for log uniform distribution function
c	-	"Cut-off" limit for log triangular distribution function
Subscripts: $_R$	-	Denotes parameter involved in the probability of damage versus distance to the ground zero relationship
$_P$	-	Denotes parameter involved in the probability of damage versus calculated peak pressure relationship

I. INTRODUCTION

There is an ever growing consensus that future military operations will require more precision than was called for, or possible, in the past. In this context, precision refers to the ability to inflict the maximum possible damage to intended targets while at the same time minimizing the undesired damage to collateral targets. The need for such precision of military actions is emphasized, in particular, in the instance of a possible NATO-Warsaw Pact nuclear conflict and in potential selective nuclear response options.

An essential part of attaining attack precision is the selection of aimpoints for the nuclear weapons. In turn, proper aimpoint selection depends upon the accuracy with which the damage expected to be sustained by the intended target as well as by nearby personnel and property can be estimated. Thus, the useful application of the aimpoint selection process requires the existence of accurate knowledge concerning the damage potential of the several weapons effects (i.e., nuclear radiation, thermal radiation, and air blast) as a function of distance from the ground zero of the weapon and of the characteristics of the target element. (These damage potentials are commonly expressed in terms of R_{50} and σ_d, where R_{50} is the distance at which the probability of damage is 0.5 and σ_d is the so-called distance-damage sigma, which is related for cumulative log normal damage laws to the standard deviation of the probability of damage versus distance relationship.)

The consequence of inaccurate knowledge of these damage potentials depends on the nature of the inaccuracy and whether intended or unintended damage is being considered. At the high probabilities of damage that are implicit in considerations of intended damage, modest levels of inaccuracy will not result in a significant misestimate of the level of damage.

At the low probabilities of damage that are implicit to considerations of collateral damage, the results are fairly sensitive to inaccurate knowledge. On the one hand, if the damage potentials were underestimated, the level of unintended damage created by the weapon would be much greater than anticipated. On the other hand, overestimation of the damage potential of a weapon could cause important military targets, which were in fact suitable for attack, to be eliminated from the attack. Both of these consequences are undesirable.

In the case of blast damage to structures, the parameters relating damage potential to distance (i.e., R_{50} and σ_d) are related to the construction characteristics of a structure class through the mean and the standard deviation of the probability of damage relationship based on analyses of damage to Japanese structures at Hiroshima and Nagasaki.

While the overall practice appears to be fairly sound, certain questions can be raised as to the relevancy of applying the results of analyses to considerations of both intended and unintended damage in scenarios involving, say, potential NATO-Warsaw conflicts. Primary among these are the following questions:

a). Are the values of σ_d, the distance-damage sigma, estimated from damage criteria that are orientated toward intended damage to structures applicable to other damage criteria that perhaps may be more consistent to collateral damage considerations?

b). Are the values of σ_d that are derived from the mix of structures within a given structural class that were present at Hiroshima and Nagasaki really appropriate to the mix of structures within the same general structure class that may be present in, say, Europe?

c). Can the Japanese structural damage data shed any light on a preferred form of the probability of damage versus distance (or pressure) relationship?

The efforts reported in this document attempt to illuminate the answers to these and other related questions through a reexamination of the structural damage to buildings at Hiroshima and Nagasaki. These efforts were divided into two basic tasks or phases. The first phase was a Data Base Compilation phase, where the primary emphasis was on reviewing source documents such as the U.S. Strategic Bombing Survey Reports for Hiroshima and Nagasaki (References 1 and 2) to establish the damage levels of the various buildings for each of two damage criteria, and also to establish, as far as possible, the major construction characteristics (i.e., wall thickness, roof type, etc.) of each building to be included in the data base. The second phase was a Statistical Analysis phase whose purpose was to establish for each of the various structure categories and damage criteria to be considered a "best" estimate of the value of σ_d, the distance-damage sigma, plus an evaluation of the potential uncertainties in these "best" estimate values.

The remainder of the report is organized in the following manner: Section II contains the Summary Observations of the Study; Section III summarizes ground rules and the results of the Data Base Compilation phase of the effort; Section IV gives the Methodology and Assumptions used in the Statistical Analysis phase of the effort; and Section V summarizes the results of the Statistical Analysis of the Japanese data and compares these results with the available structural damage data taken at the Nevada Test Site.

Two appendices are also included in this report. The first of these appendices lists every building included in the derived Japanese data base along with its structural classification and damage level. The second of the appendices shows the basic data and the results of the Statistical Analyses for every building category and subcategory and damage criteria considered in the study.

II. SUMMARY OBSERVATIONS

The principal sources of information on blast damage to structures at Hiroshima and Nagasaki are the Reports of the United States Strategic Bombing Survey (References 1 and 2) and the Reports of The Bureau of Docks and Yards Mission to Japan (References 3 and 4). These sources reported on the blast damage to various buildings in terms of the fraction of the building damaged according to two general damage criteria, Structural and Superficial. Structural Damage was defined to involve damage to the principal load-bearing members of a building, while Superficial Damage was defined to involve damage to the exterior non-load-bearing members of a building (excluding glass damage).

The available information allows for the quantification of the blast damage in terms of the fraction of the building damaged according to each of four separate damage criteria. These are:

1). Structural Damage to Walls

2). Structural Damage to Roofs

3). Structural Damage to Building (defined to be the maximum of the wall and roof damage)

4). At Least Superficial Damage.

The damage to a total of 713 buildings, with major structure classifications of Single-Story and Multistory Masonry Load-Bearing-Wall, Single-Story and Multistory Wood Frame, Single-Story Light Steel Frame, and Single-Story and Multistory Heavy Steel Frame Buildings can be classified in this manner from the available information. The number of buildings in any one structure classification is, however, quite variable, ranging from 40 Single-Story Heavy Steel Frame Buildings to 346 Single-Story Wood Frame Buildings.

In addition to describing the buildings in terms of the generic structure classifications mentioned above, the survey teams gave the construction details of a large fraction of the buildings whose damage is described

in the referenced document. This has enabled the subclassification of certain of the buildings within a given structure type according to wall thickness or type and roof type. The number of buildings within any particular subclassification is, of course, reduced from the number contained in the major structure classification.

The Hiroshima Strategic Bombing Survey Team also qualitatively compared the Japanese buildings at Hiroshima with U.S. buildings of the same structure classification. The Masonry Load-Bearing-Wall Buildings were generally somewhat stronger, the Wood Frame Buildings were somewhat weaker, and the Steel Frame Buildings were generally about the same strength as similar U.S. buildings of the same era.

Because of the relative sparsity of data points in the regions of interest, the principal analytical tool used in the Statistical Analyses of the structural damage data is the Maximum Likelihood Estimate technique. The basis of this technique is to take an assumed form of the probability of damage versus distance to the ground zero (or calculated peak pressure) relationship and to determine the particular probability of damage relationship that has the highest likelihood of having produced the observed damage at Hiroshima and/or Nagasaki. The particular values of R_{50} and σ_d (or P_{50} and σ_d) that result from this process are denoted as the Maximum Likelihood Estimates (MLE's) of these parameters.

The Maximum Likelihood Estimate technique also permits the establishment, from the observed damage data, of quasi-elliptical regions, roughly centered around the MLE values, where there is a given confidence level that the true values of R_{50} and σ_d (or P_{50} and σ_d) are contained within the defined boundaries. The existence of these regions permits estimates of the potential uncertainties in the derived probability of damage relationships to be established.

Three different forms of the probability of damage relationship are considered in the analysis: the Cumulative Log Normal, the Cumulative Log Uniform, and the Cumulative Log Triangular. The Cumulative Log Normal is the form of damage law that is currently assumed in target damage methodology. The other two forms of damage law were "made up" to illustrate

the sensitivity of the results to the assumed damage law. The Cumulative Log Uniform and Cumulative Log Triangular Damage Laws differ from the Log Normal relationship primarily in that they are "tailless" in the sense that the probability of damage is absolute unity or absolute zero at finite distances from the ground zero, rather than the asymptotic approach to these values as the distance from the ground zero goes to zero or infinity that is the characteristic of the Cumulative Log Normal Damage Law.

Overall, the analyses of the Japanese structure damage data contained herein lead to the following general observations:

1. Only "best" estimates of the values of R_{50} and σ_d (or P_{50} and σ_d) can be made from the available data base. The true values of these parameters can only be defined to the extent that they lie somewhere within certain confidence regions.

2. The size and shape of these confidence regions are typically such that, at the 0.5 confidence level, the distance from the ground zero at which the probability of damage is some fixed value is uncertain by about ±10 percent of the distance to the ground zero found using the "best" estimate values of R_{50} and σ_d. At the 0.9 confidence level, the uncertainty is about ±20 percent of the distance found using the best estimate values of R_{50} and σ_d.

3. The "best" estimate values of σ_d depend primarily on the structure classification being considered. These "best" estimate values sometimes differ by a quite sizeable factor from the generic values normally associated with certain structure types.

4. The "best" estimate values of σ_d are relatively insensitive to the damage criteria and mathematical form of the probability of damage relationship being considered.

5. Very little insight into a preferred mathematical form for the probability of damage relationship can be gained from statistical analyses of the Japanese structural damage data. The Cumulative Log Normal Damage Law fits the data just as well (or just as poorly) as the other mathematical forms of the damage laws considered in these analyses.

The rationale for the first general observation is primarily based on the nature of the Japanese structural damage data. The number of data points and location of these data points relative to the distance to the ground zero are non-ideal from a statistical analysis standpoint. This forces the use of statistical techniques that provide only estimates of the key parameters of assumed probability of damage relationships. This in itself would not be as serious a problem if there were multiple repetitions of the same experiment available. The Hiroshima data and the Nagasaki data, however, can not even be thought of as two repetitions of the same experiment, since the locations of the buildings relative to the ground zero, the weapon yields, and the height-of-bursts are different.

The uncertainty between the "best" estimate values of R_{50} and σ_d and the true values of these parameters depends on the nature of the available data set. With reasonably good data sets the maximum uncertainties in the values of R_{50} and σ_d are about a factor of 1.05 and 1.20, respectively, at the 0.5 confidence level. At the 0.9 confidence level, the corresponding factors are about 1.1 and 1.5, respectively. This means, for example, for a case where the "best" estimate values of R_{50} and σ_d are 7.30 Kft and 0.23, respectively, at the 0.5 confidence level, the true value of R_{50} can only be defined as being somewhere between about 7.0 and 7.7 Kft, and the true value of σ_d can only be defined as being somewhere between 0.19 and 0.28. At the 0.9 confidence level, the true value of R_{50} can only be defined as being somewhere between 6.6 and 8.0 Kft, and the true value of σ_d can only be defined as being somewhere between 0.16 and 0.37.

The rationale for the second general observation is the natural result of the existence of the uncertainties in the true values of R_{50} and σ_d. Every possible pair of values of R_{50} and σ_d creates a unique probability of damage versus distance relationship. The envelope that bounds all of the possible probability of damage versus distance relationships for a given confidence level then determines the uncertainty regions for the true probability of damage versus distance relationship at this confidence level.

The size of these uncertainty regions in the probability of damage relationship depends primarily on the nature of the data set being used.

The quoted values of ±10 and ±20 percent at the 0.5 and 0.9 confidence levels are representative of the values derived from a reasonably good data set (i.e., Structural Damage to Single-Story Masonry Load-Bearing-Wall Buildings). The uncertainty regions in the probability of damage relationship for Structural Damage to Multistory Load-Bearing-Wall Buildings and Single-Story and Multistory Wood Frame Buildings are of a generally similar size, while the uncertainty regions in the probability of damage relationships for Structural Damage to Light and Heavy Steel Frame Buildings are somewhat larger than these ±10 and ±20 percent values.

The rationale for the third general observation is the observed variation in the "best" estimate values of the distance-damage sigma with structure classification and subclassification. For the Single-Story and Multistory Masonry Load-Bearing-Wall and Wood Frame Buildings, the value of σ_d for the Structural Damage criteria was found to range from about 0.10 to 0.35 (with the Multistory buildings having the lower values of σ_d) compared to the generic value of 0.20 normally assigned to these structure classifications.

Efforts to reduce the value of the distance-damage sigma through subclassification of structure types met with modest success at most. Removal of obviously "odd ball" buildings from a given structure classification reduced the value of σ_d by some 10 to 20 percent in the cases of the Single-Story Wood Frame and Light Steel Frame Buildings. The Multistory Wood Frame Buildings represent a form of subclassification in themselves. A large portion of these buildings were schools of generally similar dimensions and construction, and the damage data for these buildings dominate the results for this structure classification. These data thus give an indication that the value of σ_d for a very carefully defined structure class may be somewhat lower than the values found for the general structure classifications assigned to the Japanese buildings.

The rationale for the fourth general observation is partially based on the observation variations in the value of σ_d for a given structure class under various assumptions as to damage criteria and damage law, and is partially based on certain properties of the damage laws considered in these analyses. The differences, if any, in the value of σ_d derived for

the Structural Damage to Building and the At Least Superficial Damage criteria are of particular interest in the case of the Cumulative Log Normal Damage Law. This damage law has the property that two probability of damage versus distance relationships with different values of σ_d will cross somewhere in the distance regime. Thus, if the value of the distance-damage sigma were different for the two damage criteria, there would be a distance regime in which the probability of At Least Superficial Damage was less than the probability of Structural Damage to the Building. This, of course, is an absurdity. The probability of At Least Superficial Damage must always be equal to or greater than the probability of Structural Damage to the Building. Thus, if the Cumulative Log Normal is the true damage law, the values of the distance-damage sigma must be identical for these two damage criteria. The "best" estimate values of σ_d for certain structure classes are near enough to being identical to lend credence to this Cumulative Log Normal Damage Law hypothesis.

The Cumulative Log Uniform and Cumulative Log Triangular Damage Laws do not require that the value of the distance-damage sigma be identical for the Structural to Building and Superficial Damage criteria. There are, however, certain limits on the relative values of σ_d to avoid the same absurdity as mentioned in the discussion in the previous paragraph. The "best" estimate values of σ_d derived using these damage laws are, however, so similar to the values derived using the Cumulative Log Normal Damage Law that is is difficult to argue that the value of σ_d varies between these two damage criteria.

The differences, if any, in the value of σ_d and P_{50} for the Structural Damage to Walls, Structural Damage to Roofs, and Structural Damage to Building damage criteria are also of interest. The Structural Damage to Building is like a combined effects criteria in that it represents the maximum of the damage to the walls or roof of the building. If the Cumulative Log Normal Damage Law were the true damage law for the Structural Damage to Walls and Structural Damage to Roofs damage criteria, then the damage law for the Structural Damage to Building criteria would only be approximately Log Normal with a value of σ_d that is somewhat smaller than

the larger of the σ_d's and a value of P_{50} that is somewhat smaller than the lesser of the values of P_{50} for the Structural Damage to Walls and Roofs damage criteria. The "best" estimate values of σ_d are generally consistent with this sort of behavior but the values of P_{50} are not.

The rationale for the fifth general observation stems partially from the basic nature of the damage laws considered in these analyses and partially from the nature of the available Japanese (and NTS) structural damage data. The three damage laws considered in the analyses are such that if the value of σ_d and R_{50} (or P_{50}) were identical for all three damage laws, the maximum difference in the probability of damage at any fixed distance from the ground zero is about 0.06. Even in the cases where different values of R_{50} and σ_d are found on fitting the various damage laws to the damage data, the maximum differences in the "best" estimate probability of damage values at some fixed distance from the ground zero are in the neighborhood of 0.10. Goodness-of-fit tests with the number and quality of data points available from these structural damage data are simply not precise enough to discern these sorts of differences.

The principal impact of these results is the degree of uncertainty that must be accepted with any probability of damage versus distance to the ground zero relationship. This degree of uncertainty is such that the probability of damage values derived using the "best" estimate values of R_{50} and σ_d are almost certainly incorrect, since the "best" estimate probability of damage versus distance relationship <u>does not</u> give the expected values of the probability of damage at fixed distances from the ground zero but rather defines the probability of damage value such that there is a 0.5 confidence level that the <u>true</u> value of the probability of damage is no greater.

This distinction is probably of minimal importance when dealing with intended damage and laydown criteria that imply "do as well as you can." When dealing with laydown criteria that involve greater precision, however, the degree of uncertainty in the definition of the probability of damage at fixed distances from the ground zero must certainly be taken into account.

One way in which this could be done is to use conservative values for the probability of damage versus distance relationship. Intended damage could be based on the relationship that has the property that there is, say, 0.9 confidence that the probability of damage at any distance from the ground zero is at least the calculated value, while collateral damage could be based on the relationship such that there is, say, a 0.9 confidence that the probability of damage at a given distance from the ground zero is no more than the calculated value.

As an example, consider the case of 100 percent Structural Damage to Walls (i.e., wall collapse or insipient collapse) of Masonry Load-Bearing-Wall Buildings with walls 7 to 14 inches thick. Taking first a case that is perhaps representative of intended damage, at the point where the "best" estimate value of the probability of damage is 0.9, Monte Carlo model results based on 1000 samples show that there is approximately a 0.9 confidence level that the probability of damage is at least 0.755 and a 0.95 confidence level that the probability of damage is at least 0.725. Treating next a case that is perhaps representative of collateral damage, at the point where the "best" estimate probability of damage is 0.05, the Monte Carlo results indicate that there is approximately a 0.9 confidence level that the probability of damage is no more than 0.195 and approximately a 0.95 confidence level that the probability of damage is no more than 0.245.

While these probability of damage values may appear to be excessively small or large, they represent the "best" estimates that can be made at this time if high confidence intended and collateral damage calculations are to be made. The only feasible method for significantly reducing these uncertainties in the probability of damage values appears to be to add additional test site structural damage data to the appropriate Japanese structural damage data. For example, adding the structural damage levels for the three Masonry Load-Bearing-Wall Buildings that were exposed to blast in the "Dice Throw" experiment increases the 0.9 confidence probability of damage value for the intended case from 0.755 to 0.78 and

reduces the 0.9 confidence probability of damage value of the collateral damage case from 0.195 to 0.165. While these changes are relatively modest, it should be kept in mind that they represent increasing the number of data points for the particular structure classification from 42 to 45 through the addition of three high-quality data points.

III. DATA BASE COMPILATION

The primary sources of information for the data base compilation efforts were the U.S. Strategic Bombing Survey (USSBS) Reports for Hiroshima and Nagasaki (References 1 and 2 . The reports of the U.S. Navy Bureau of Docks and Yards Mission to Japan on Hiroshima and Nagasaki (References 3 and 4), the report of the Manhattan Engineering District on Hiroshima and Nagasaki (Reference 5), and the unpublished notes and working papers of the Strategic Bombing Survey teams that are contained in the National Archives (Reference 6) were also valuable sources of information for buildings that were, for unknown reasons, not included in the formal Strategic Bombing Survey Reports.

The actual on-the-ground structural damage surveys of the Strategic Bombing Survey group were conducted by two different survey teams, one at Hiroshima during the period from 14 October 1945 through 26 November 1945, and the other at Nagasaki during the period from 14 October 1945 until 18 November 1945. Thus, the survey teams were on site for some six weeks at Hiroshima and five weeks at Nagasaki, and the on-the-ground surveys did not start until about 11 weeks after the actual detonations of the atomic weapons at the two cities.

Both survey teams reported the damage to the various buildings according to two damage criteria: Structural Damage and Superficial Damage. Structural Damage was defined to be:

> "Damage to Principal Load-Carrying Members (Trusses, Beams, Columns, Load-Bearing Walls, Floor Slabs in Multistory Buildings) Requiring Replacement or External Support During Repair."

Superficial Damage was defined to be:

> "Damage to Purlins and Other Light Members, Stripping of Roofing and Non-Load-Bearing Exterior Walls. Damage to Glass and Interior Partitions Not Included."

The two survey teams used the same general structural classifications (i.e., Wood Frame, Masonry Load-Bearing-Wall, etc.) but used different formats for reporting the data. The Hiroshima team generally used a Summary Data Sheet (see Table 1), a Construction Sketch that indicated the portions of the building that were damaged, and one or more photographs showing the extent of damage to the building. The Nagasaki team generally used a different form of Summary Data Sheet (see Table 2), one or more photographs showing the building damage, but did not generally include a Construction Sketch for each building reported. The two teams also reported quantitative damage levels in different terms. The Hiroshima team reported in terms of the percent of the total floor area that received a given damage level. The figure used was the maximum of the fractional damage to either the wall or the roof of the building. The Nagasaki team reported separately in terms of the fraction of the walls, roof, etc., that received the specified damage level.

The Hiroshima SBS Survey Team also made a qualitative comparison of every building that they surveyed with usual U.S. buildings of the same structure class. They found, in general, that the Masonry Load-Bearing-Wall Buildings were somewhat stronger, Wood Frame Buildings were somewhat weaker, and Steel Frame Buildings were about the same as corresponding U.S. buildings of this era.

The reports of the U.S. Navy Bureau of Yards and Docks Mission to Japan were written by Navy personnel that were assigned to the on-site inspection team at Nagasaki. This group spent the period from 26 October through 8 November 1945 at Nagasaki and the period from 8 November to 24 November 1945 at Hiroshima.

Their report on Nagasaki contains no information on buildings that were not included in the USSBS reports. Their report on Hiroshima, however, contains information on a fairly large number of buildings that were not, for unknown reasons, included in the USSBS reports. The

TABLE 1

TYPICAL DAMAGE SUMMARY SHEET

Hiroshima Physical Damage Survey Team

U.S. STRATEGIC BOMBING SURVEY

Physical Damage Division

Field Team No. 1, Hiroshima, Japan

BUILDING ANALYSIS

Building No.: 72. Coordinates: 311. Distance from (GZ): 6,200, (AZ): 6,500.

NAME: Toyo Light Alloy Co.

CONSTRUCTION AND DESIGN
Type: Brick-bearing wall, wood trusses supported on internal columns
Number of stories: 1. JTG class: Al 1.
Roof: Corrugated iron on wood trusses.
Partitions: None.
Walls: 13-inch brick, load-bearing with pilasters.
Floors: Concrete on earth.
Framing: Timber truss and lally columns interior.
Window and door frames: Wood. Ceilings:
Condition, workmanship, and materials: Fair workmanship; wood shows appreciable dry rot.
Compare with usual United States buildings: About same.

OCCUPANCY: Foundry, aluminum.

CONTENTS: Gas fired furnaces, molds, flasks, work benches.

DAMAGE to building: Walls normal to direction of blast collapsed to foundation level. Roof trusses displaced away from blast and dropped to floor buckling columns, roofing stripped. Small amount of fire damage. Cause: Blast.

DAMAGE to contents: Moderate damage to contents, with furnaces lightly damaged. Cause: Debris (20 percent). Fire (10 percent).

TOTAL FLOOR AREA (square feet): 13,000. Structural damage: 13,000. Superficial damage:

FRACTION OF DAMAGE: Building structural: 100 percent. Superficial: Contents: 30 percent.

REMARKS: Contents' damage based upon observation only. Most tools and small equipment had been removed following bombing.

Note: Building damage based on total floor area. Contents damage is fraction of contents seriously damaged.

TABLE 2

TYPICAL DAMAGE SUMMARY SHEET

Nagasaki Physical Damage Survey Team

DAMAGE ANALYSIS

Dimensions: 95 by 22 feet.	Group 40.
Ground floor area: 2,090 square feet.	Building No. 3.
Total area: 2,090 square feet.	Occupancy: Storage.
Number of floors: 1.	Building type: 1-story brick wall warehouse (D).
Eave height: 18 feet.	Fire classification: Noncombustible.
Mean elevation: 10 feet.	Ground zero: 6,300 feet.

Construction	DAMAGE			Description of damage
	Structural (%)	Superficial (%)	Cause	
Roof: CGI on steel L-purlins	0	100	Blast	Demolished.
Trusses: Simple, steel; 3- by 3-inch L-members, bolted to walls.	100	0	---do--	Crippled and fallen.
First floor: Concrete on earth	0	0		
Foundation: Concrete or brick footings.	0	0		
Exterior walls: 12-inch brick: 4- by 16-inch pilasters 10 feet by 6 inches o.c.	60	0	Blast	North and east walls almost entirely wrecked; south wall cracked and partly wrecked; west wall almost intact.
Windows: Bars and fire shutters only -- no glass.	0	100		Shutters blown off.
Contents: NA.				

construction details and damage levels in these reports are presented in a qualitative fashion only but do allow calibration to the USSBS reported values, since the Navy team attempted to report on the damage to every building at Hiroshima that was reported on by the Strategic Bombing Survey team.

For example, the Docks and Yards report identified Building 72 at Hiroshima (described in Table 1) to be the Needle Manufacturing Plant located 6200 feet north of the ground zero. The building description is given as "saw tooth, timber roof trusses with corrugated metal roofing, brick walls, cast-iron interior columns, 134 feet by 86 feet" and the damage is described as "the trusses and all walls except the west wall collapsed. The columns are ruptured. There was a fire after the collapse."

This description is generally in good agreement with the Strategic Bombing Survey results shown in Table 1. The building size quoted by the Navy group is about 10 percent smaller than the size given by the Strategic Bombing Survey report.

Other reported damage values in the Docks and Yards report are, however, obviously in error. The Navy team, on occasion, could not find the building, or reported on the damage to an abviously different building than the one identified by the Bombing Survey team.

The Manhattan Engineering District's report on Hiroshima and Nagasaki is an extremely qualitative document that represents the views of the earliest American survey groups who performed on the ground inspections at Hiroshima and Nagasaki. Their preliminary surveys were conducted on the 8th and 9th of September at Hiroshima and the 13th and 14th of September at Nagasaki. These survey teams spent a total of four days at Hiroshima and 16 days at Nagasaki.

After reviewing these source documents, the following ground rules were established for including or excluding the various buildings from the data file being constructed:

a). Reinforced concrete frame buildings generally would not be included in the structural damage data file. A few buildings of this type that did not have reinforced concrete roofs were included on the basis of roof damage only. This type of building was included, however, in the glass damage data file in the cases where glass breakage information was given.

b). No building that had been hit or damaged by conventional H.E. bombs would be included.

c). No building whose level of blast damage was masked by fire damage would be included.

d). No building that was being dismantled by the Japanese at the time of the survey would be included.

e). Steel frame buildings that were in the Regular Reflection Region would not be included.

It was also decided to carry the damage-distance data according to the general format of the Nagasaki Strategic Bombing Survey Report in terms of:

a). Distance to Ground Zero (to nearest 100 feet)

b). Structural Damage to Walls

c). Structural Damage to Roofs

d). At Least Superficial Damage to Building

e). Glass Damage.

The reformatting of the Strategic Bombing Survey's Hiroshima data was done on the basis of the building sketches, photographs, and verbal damage descriptions contained in the data sheets. See, for example, Table 1.

The number of buildings in the data base derived by these efforts is shown in Table 3. Also shown are the number of buildings in the data base which will be referred to as TM-4. While the new data base generally has a larger number of buildings of each class than does the TM-4 data base, there are two cases where the number of buildings has actually decreased. The Multistory Masonry Load-Bearing-Wall Buildings at Nagasaki were decreased by one on the basis of fire damage masking any blast damage to this building. The Single-Story Heavy Steel Frame Buildings at Nagasaki were decreased by five on the basis of one building being misclassified by TM-4 and four buildings being hit by H. E. bombs.

In addition to categorizing the various buildings according to the major classifications shown in Table 3, it was attempted to subclassify each building according to wall and roof characteristics. These subclassifications were derived on an ad hoc basis in an attempt to account for discernible differences within each structure classification.

While certain of the structure subclassifications were rather obvious, others were arrived at by examining structures that appeared to be significantly "harder" or "softer" than other apparently similar structures at similar distances from the ground zero. Checks were made on whether the building was shielded from the effects of the blast wave by other buildings, or whether there were geometric correlations with the locations of the other significantly "harder" (or "softer") buildings, the orientation of the building to the blast wave, and then on whether there was a discernible difference in the construction of the building under consideration.

As a by-product of these subclassification efforts, it was observed that there are only two cases where shielding from the effects of blast wave apparently occurred, and that there was no discernible geometric correlation at Hiroshima between buildings that were either much "harder"

TABLE 3

NUMBER OF BUILDINGS IN DATA BASES

Major Classification		New Data Base		TM-4 Data Base	
Type	Stories	Hiroshima	Nagasaki	Hiroshima	Nagasaki
Masonry-Load-Bearing-Wall	Single	49	52	14	24
	Multi	33	10	19	11
Wood Frame	Single	81	265	15	23
	Multi	22	41	12	12
Light Steel Frame	Single	43	47	19	32
Heavy Steel Frame	Single	2	38	0	43
	Multi	2	28	0	0
Any (Glass Damage)	Any	224	481	0	0

or much "softer" than other buildings with similar structural characteristics. There was also no apparent orientation to the blast wave effects for the Masonry Load-Bearing-Wall and Wood Frame Buildings. The number of buildings that received unexplainably large or small structural damage levels was also reduced to two, both at Nagasaki. One is a Light Steel Frame Building with the identifier 52-12C6; the other is a Single-Story Wood Frame Building with the identifier 92-1.

The wall and roof subclassifications for the four major structure classifications derived from this effort are shown in Table 4. The efforts of identifying the subclassifications for each building met with varying degrees of success. For example, the wall thickness of the Masonry Load-Bearing-Wall Buildings could be established for about 60 percent of the buildings in the data base. The attempt to further subclassify the Steel Frame Buildings according to column size met with failure, since column size could be established for only about one-fourth of these buildings and no ready correlation between I-beam and lattice work columns could be established.

The complete listing of the buildings contained in the final data base is given in Appendix A. In addition, a listing of the major buildings that were excluded from the data base and the reasons for their exclusion are also given in this appendix.

TABLE 4

STRUCTURE SUBCLASSIFICATIONS

MAJOR CLASSIFICATION	WALLS	ROOF
Masonry Load-Bearing-Wall	7 to 9 Inch 12 to 14 Inch 17 to 19 Inch 23 to 27 Inch	Reinforced Concrete Steel Roof Trusses Cover Material Fails Slowly* Cover Material Fails Quickly* Wood Roof Trusses Cover Material Fails Slowly Cover Material Fails Quickly
Wood Frame	Normal Walls Wall Cover Material Fails Quickly (or No Wall Cover) Heavy Crane Columns	Steel Roof Trusses Cover Material Fails Slowly Cover Material Fails Quickly Wood Roof Trusses Cover Material Fails Slowly Cover Material Fails Quickly
Steel Frame (Light and Heavy)	Wall Cover Material Fails Slowly Wall Cover Material Fails Quickly Very Light Columns Concrete Panel Walls Reinforced Concrete Walls Concrete Filled Columns	Reinforced Concrete Steel Roof Trusses Cover Material Fails Slowly Cover Material Fails Quickly Wood Roof Trusses Cover Material Fails Slowly Cover Material Fails Quickly

*The categorization of wall and/or roof cover materials failing slowly or quickly was devised to account for the different behavior of materials such as corrugated iron and corrugated asbestos. Corrugated asbestos is defined to fail quickly. All other cover materials are defined to fail slowly.

IV. METHODOLOGY AND ASSUMPTIONS

The basic problem addressed in the Statistical Analysis phase is to take the observed damage to the buildings at Hiroshima and Nagasaki and to estimate the probability of damage versus distance to the ground zero (or probability of damage versus peak pressure) relationship that produced the observed damage.

Ideally, this would be done by establishing relatively small distance intervals (or pressure intervals) and establishing the fraction of the buildings within each interval that were damaged to at least the given damage criteria. If there were a sufficiently large number of buildings within each interval, the fraction of buildings within each interval that was damaged and the average probability of damage over the interval would then be nearly identical. The mathematical form of the probability of damage relationships could then be found by simple trial and error curve fits of the data to various assumed probability of damage versus distance to the ground zero (or peak pressure) relationships.

Implicit in this idealized methodology are numbers of buildings in the range of hundreds to thousands, rather than the tens to hundreds of buildings contained in the entire Japanese structural damage data base. There is also the implication of much greater order in the locations of the various buildings than is exhibited in the results of the Hiroshima and Nagasaki damage surveys.

The typical form of the basic damage versus distance to the ground zero data contained in the data base is illustrated in Figures 1 and 2. For the particular structure class and damage criteria shown, the Hiroshima data (Figure 1) show the fraction damaged to at least the given criteria for the individual buildings to be 1.0 out to a distance of about 4000 feet from the ground zero. Between about 5500 and 8500 feet from the ground zero, the fraction of the individual buildings damaged to the given criteria ranges anywhere between 1.0 and 0.0. Beyond

FIGURE 1

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
STRUCTURAL DAMAGE CRITERIA

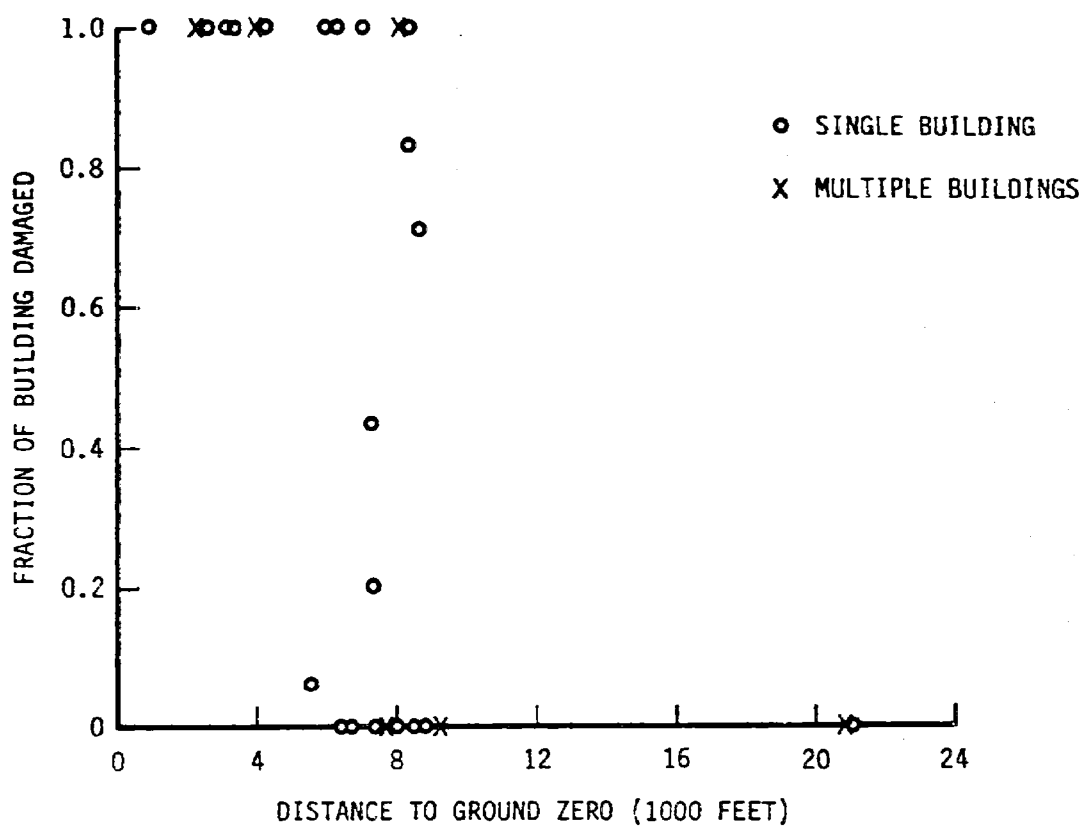
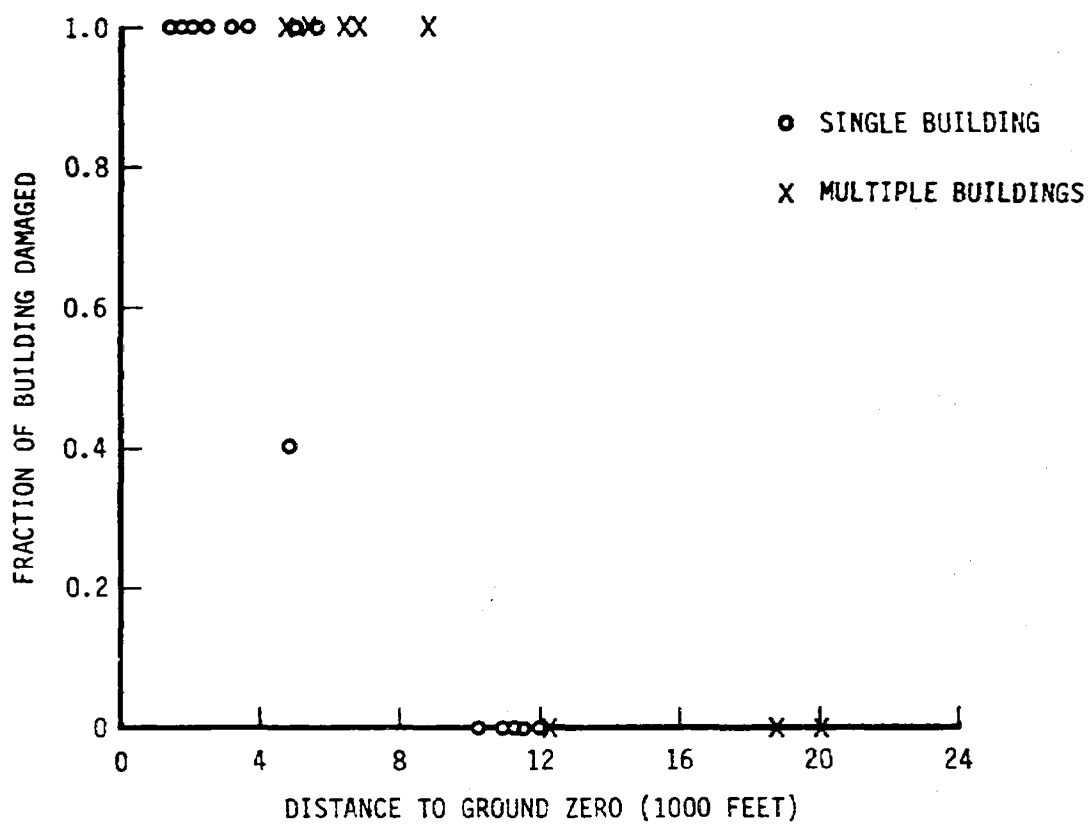


FIGURE 2

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE CRITERIA



about 8500 feet from the ground zero, the fraction of the individual buildings damaged to the given criteria is zero for this data set.

The Nagasaki data (Figure 2) show somewhat similar behavior. With the exception of the one building at about 5000 feet from the ground zero, the fraction damaged to the given criteria for the individual buildings is 1.0 out to about 9000 feet from the ground zero. Beyond about 10,000 feet from the ground zero, the fraction of the individual buildings damaged to the given criteria is zero for this data set.

Overall, these two data sets show some undesirable properties that occur quite frequently with the Japanese damage-distance data. The Hiroshima data set has no data points in the region from about 10,000 to 21,000 feet from the ground zero. The Nagasaki data set has a sparcity of data points in the region from about 7000 to 10,000 feet from the ground zero, and has a complete lack of data points in the region from 13,000 to 19,000 feet from the ground zero. This trend for data to be sparce or missing over major distance regions makes the Japanese damage data, at first sight, somewhat less valuable than the sheer number of data points might imply.

A. MAXIMUM LIKELIHOOD ESTIMATE TECHNIQUE

The Maximum Likelihood Estimate technique was used as the tool for making <u>point estimates</u> of the key parameters of the probability of damage versus distance to the ground zero relationship from the basic damage versus distance data. The basis for this technique is to define a Likelihood Value for each building in the data set under consideration and to determine the key parameters of the <u>assumed probability of damage relationship</u> that maximizes the product of these Likelihood Values (which is called the Likelihood Function) when taken over all the buildings in the data set.

The particular form of the Likelihood Value used in the analysis is:

$$L_i = p_i^{d_i} \cdot (1-p_i)^{d_i} \qquad (1)$$

where

p_i = assumed value of the probability of damage for the i^{th} building in the data set

d_i = the observed fraction of the building damaged to at least the specified criteria,

and the Likelihood Function is

$$L = \prod_{i=1}^{n} p_i^{d_i} (1-p_i)^{1-d_i} \tag{2}$$

where n is the number of buildings in the particular data set. The values of the key parameters of the assumed probability of damage versus distance to the ground zero relationship that maximize the Likelihood Function are then called the Maximum Likelihood Estimate (M.L.E.) of these key parameters.

The non-zero and non-unity fraction of the building damaged values in the damage data were handled in one of two ways through the definition of the probability of damage being considered. The first method, which will be called the <u>Specified Damage Fraction</u> (S.D.F.) technique, is to define the probability of damage to be the probability of damaging <u>at least</u> a fraction X of a building's floor space (or walls or roof) to at least the given damage criteria. The fraction X will be denoted as the Specified Damage Fraction. With this technique, the fractional damage values in Equations (1) and (2) can have only the values 1 or 0, since the building is either damaged to the given fractional level or is not damaged to this level.

As an example, using the Specified Damage Fraction concept would result in the following treatment of the five buildings in the Hiroshima data set (Figure 1) with non-zero/non-unity fraction of the building damaged levels. With a Specified Damage Fraction of 0.5, the three buildings with damage levels less than 0.5 would be denoted as undamaged (i.e., d_i = 0 in Equation (2)), while the two buildings with damage

fractions greater than 0.5 would be denoted as damaged (i.e., $d_i = 1.0$). On the other hand, with a Specified Damage Fraction of 0.9, all five buildings would be treated as undamaged.

The second method of handling the non-zero/non-unity fractional damage levels, which will be called the Unspecified Damage Fraction (U.D.F.) technique, is to define the probability of damage to be the probability of expecting to damage the entire building (or alternatively, the probability of damaging an unspecified fraction of the building). With this technique, a non-unity/non-zero fractional damage value is treated as though there were multiple buildings, some of which were damaged and some of which were undamaged, but a weight of only one building is included in the Likelihood Function (Equation (2)). As an example, the data point at 7300 feet from the ground zero in Figure 1 with a fractional damage level of 0.2 is treated as though there were five buildings, one of which was damaged according to the criteria and four of which were undamaged according to the criteria.

Point estimates of key parameters of the probability of damage versus calculated peak pressure relationships are also made using the Maximum Likelihood Estimate (M.L.E.) technique. The basic damage versus distance to the ground zero data are converted to damage versus calculated peak pressure data assuming a yield and height-of-burst of 22 Kt and 1640 feet for the Nagasaki weapon, and a yield and height-of-burst of 12 (or 17 or 22) Kt and 1850 feet for the Hiroshima weapon. (The range of yields assumed for the Hiroshima weapon was chosen to reflect the range in the estimates that was available when this study was initiated.)

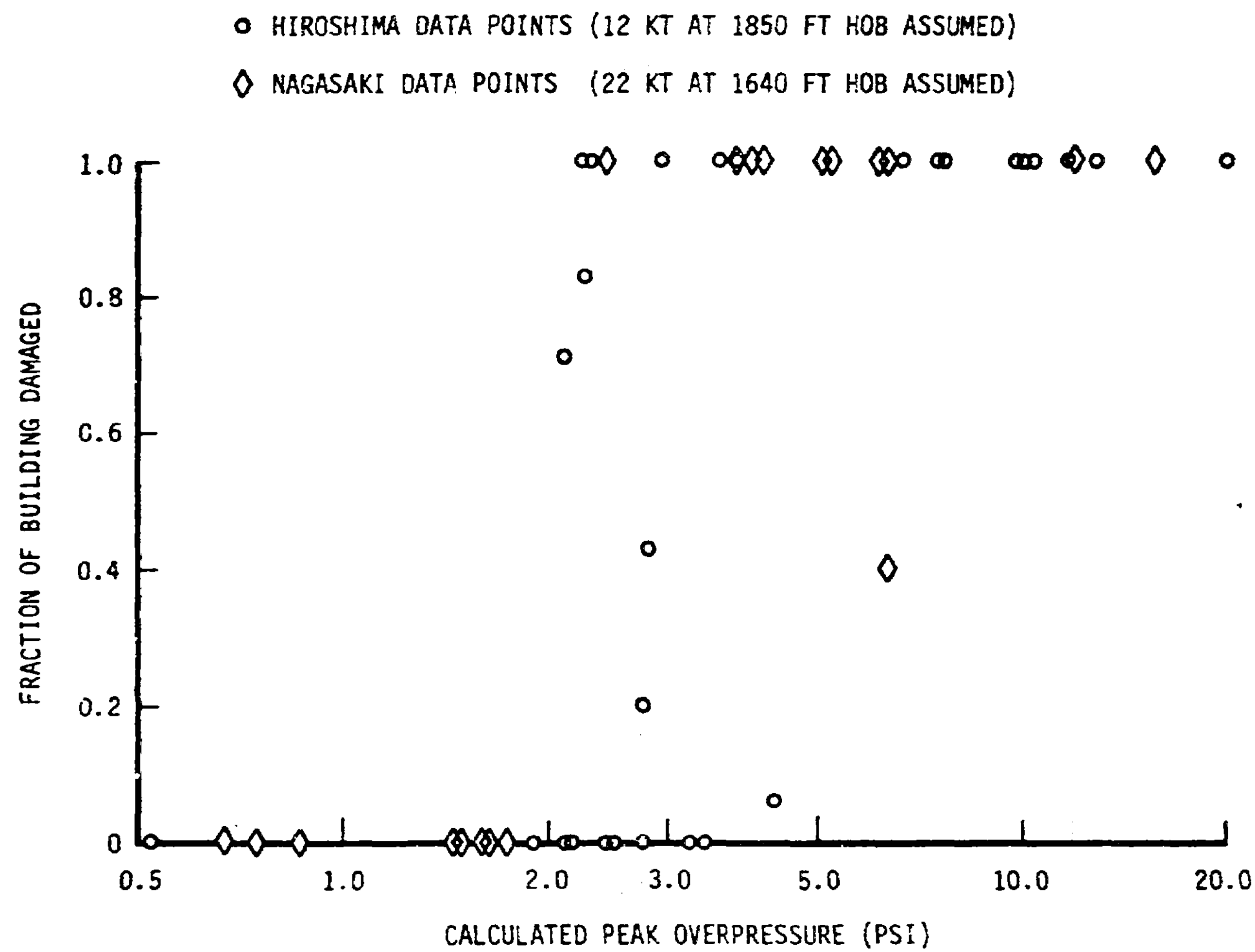
Figure 3 illustrates the results of converting the damage versus distance to the ground zero data of Figures 1 and 2 into damage versus calculated peak overpressure, and then combining the Hiroshima and Nagasaki data. (For this figure, the Hiroshima yield is assumed to be

FIGURE 3

DAMAGE VERSUS CALCULATED PEAK OVERPRESSURE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

STRUCTURAL DAMAGE CRITERIA



12 Kt.) The data set, of course, retains the same general form as observed with the basic damage/distance presentation. For this case, however, the combining of the Hiroshima and Nagasaki data through the mechanism of calculated peak overpressure results in a "better looking" data set, since the data from one city tend to fill in the gaps that exist in the data from the other city.

B. PROBABILITY OF DAMAGE RELATIONSHIPS

Three different mathematical forms of the probability of damage versus distance to the ground zero (or calculated peak pressure) relationship are assumed for the analysis. These are denoted as:

1). The Cumulative Log Normal Distribution

2). The Cumulative Log Uniform Distribution

3). The Cumulative Log Triangular Distribution.

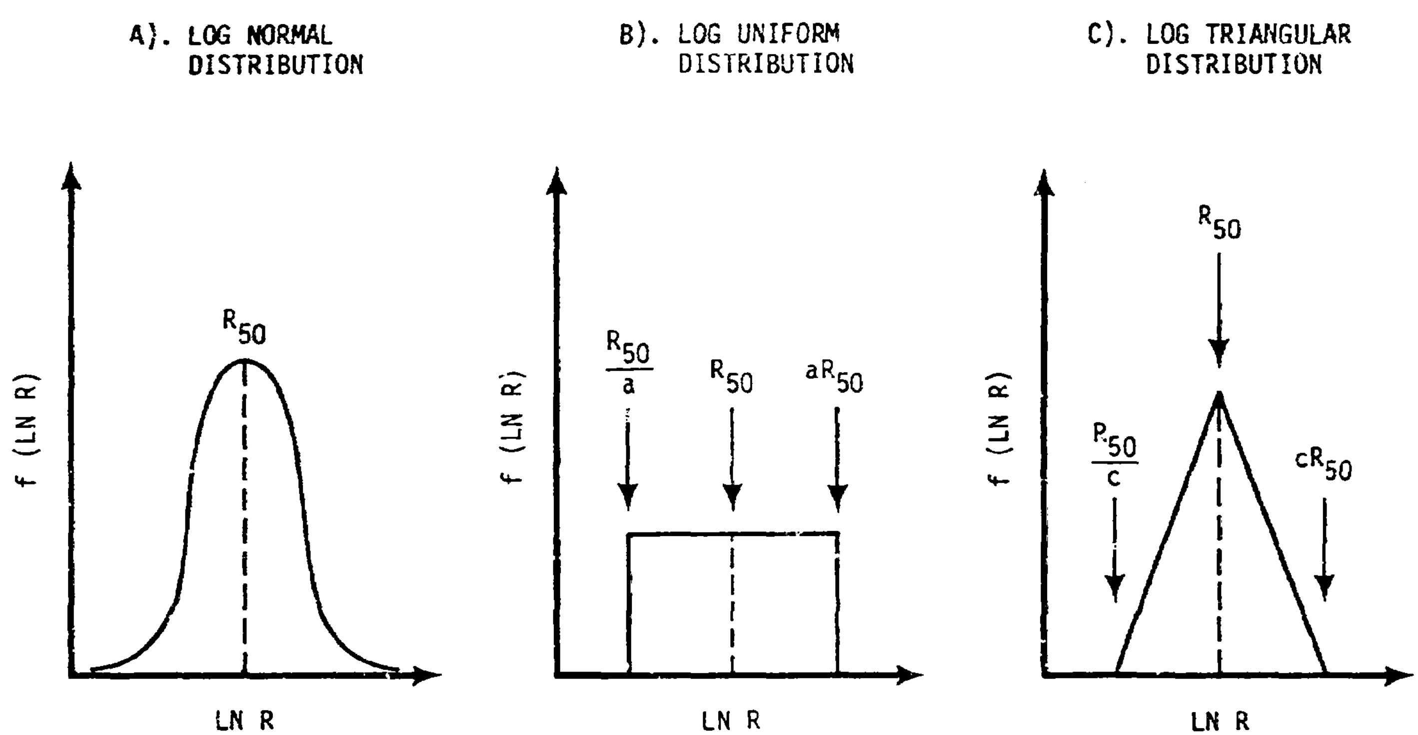
The Cumulative Log Normal Distribution function is the commonly assumed form of the probability of damage versus distance (or peak pressure) relationship. The frequency function for this distribution function has the familiar "bell-shaped" form illustrated in Figure 4, and the complete distribution function can be characterized by its mean (R_{50}) standard deviation (β_R).

The Cumulative Log Uniform and Cumulative Log Triangular Distributions were made up for use in the analysis to illustrate the sensitivity of the results to the assumed form of the probability of damage versus distance to the ground zero (or peak pressure) relationship. The forms of the frequency functions for these distributions are also shown in Figure 4.

The Cumulative Log Uniform Distribution function has a frequency function that is centered around its mean value (R_{50}) and "cut off" at the limiting distance of R_{50}/a_R and a_R R_{50}. The significance of these cut-offs is lack of tails for the distribution function. Thus, the probability of damage calculated using this distribution will have the

FIGURE 4

FREQUENCY FUNCTIONS FOR ASSUMED DAMAGE LAWS



absolute values of zero and unity at finite distances from the ground zero rather than the asymptotic approach to these values that is the property of the Cumulative Log Normal Distribution function.

The Cumulative Log Triangular Distribution has a frequency function that is somewhat similar to the Cumulative Log Uniform Distribution in that the frequency function is centered at R_{50} and has "cut-offs" at R_{50}/c_R and $c_R\ R_{50}$. The Log Triangular frequency function, however, has its greatest population density near R_{50} rather than the uniform population distribution between the cut-off limits exhibited by the Log Uniform Distribution's frequency function.

The damage laws derived from the frequency functions shown in Figure 4 have the following forms when expressed as probability of damage (P_d) versus distance to the ground zero (R):

a). Cumulative Log Normal

$$P_d(R) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\frac{\ln\left(\frac{R_{50}}{R}\right)}{\beta_R}} \exp\left(-\frac{1}{2}\,y^2\right) dy\ .$$

b). Cumulative Log Uniform

$$P_d(R) = 1.0 \qquad \frac{R}{R_{50}} < \frac{1}{a_R}$$

$$P_d(R) = \frac{1}{2\ \ln\ a_R}\ \ln\left(\frac{a_R\ R_{50}}{R}\right) \qquad \frac{1}{a_R} \leq \frac{R}{R_{50}} \leq a_R$$

$$P_d(R) = 0 \qquad \frac{R}{R_{50}} > a_R\ .$$

c). Cumulative Log Triangular

$$P_d(R) = 1.0 \qquad \frac{R}{R_{50}} < \frac{1}{c_R}$$

$$P_d(R) = 1 - \frac{1}{2 \ln^2 c_R} \ln^2\left(\frac{R_{50}}{c_R R}\right) \qquad \frac{1}{c_R} \leq \frac{R}{R_{50}} \leq 1$$

$$P_d(R) = \frac{1}{2 \ln^2 c_R} \ln^2\left(\frac{c_R R_{50}}{R}\right) \qquad 1 \leq \frac{R}{R_{50}} \leq c_R$$

$$P_d(R) = 0 \qquad \frac{R}{R_{50}} > c_R .$$

where R_{50} is the distance at which the probability of damage is 0.5, β_R is the standard deviation of the Log Normal function, and a_R and c_R are "cut-off" limits on the frequency functions for the Log Uniform and Log Triangular relationships.

The two parameter characterizations of these three functions can be converted to the Weapon Radius (WR) and distance-damage sigma (σ_d) through the relationships:

a). Cumulative Log Normal Damage Law

$$WR = R_{50} \exp(\beta_R^2)$$

$$\sigma_d^2 = 1 - \exp(-\beta_R^2) .$$

b). Cumulative Log Uniform Damage Law

$$WR = R_{50} \cdot \sqrt{\frac{a_R^2 - \frac{1}{a_R^2}}{4 \ln a_R}}$$

$$\sigma_d^2 = 1 - \frac{1}{\ln a_R} \cdot \frac{a_R - \frac{1}{a_R}}{a_R + \frac{1}{a_R}} .$$

c). Cumulative Log Triangular Damag Law

$$WR = R_{50} \cdot \sqrt{\frac{c_R^2 - 2 + \frac{1}{c_R^2}}{4 \ln^2 c_R}}$$

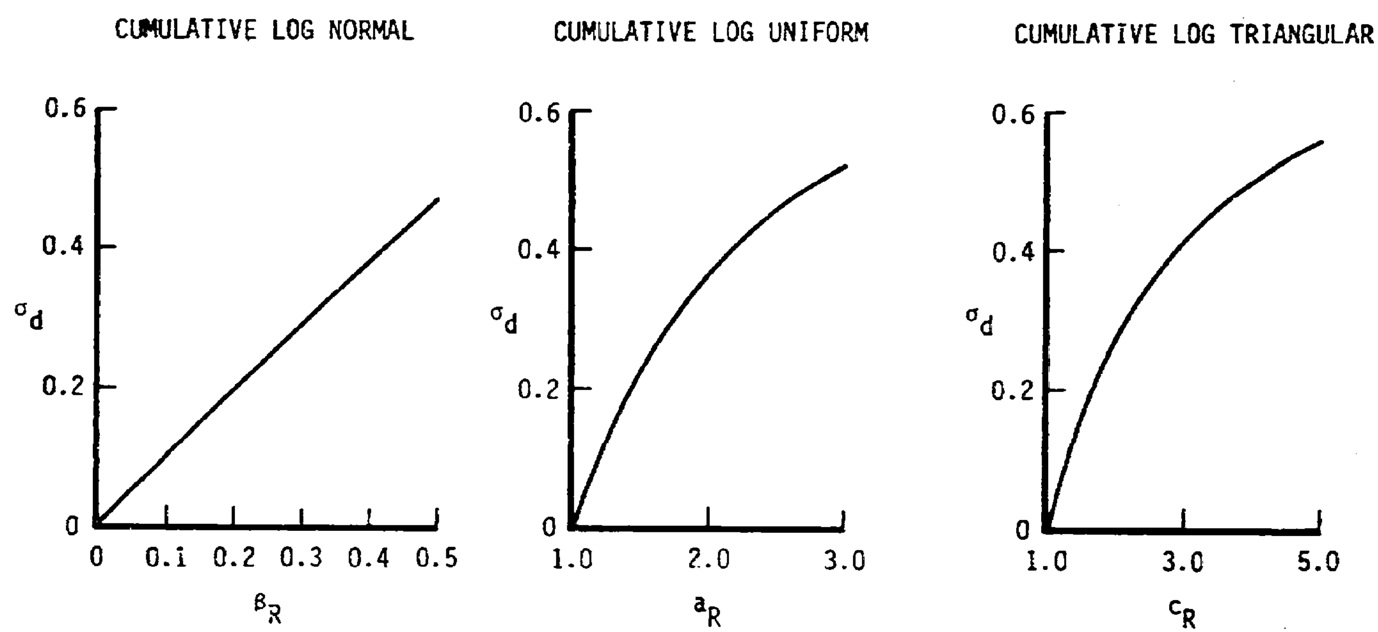
$$\sigma_d^2 = 1 - \frac{4}{\ln^2 c_R} \cdot \frac{c_R - 2 + \frac{1}{c_R}}{c_R + 2 + \frac{1}{c_R}} .$$

The variations in the value of σ_d with the standard deviation (β_R) and "cut-off" limits (a_R and c_P) are illustrated in Figure 5.

The same three mathematical forms are used for the probability of damage versus peak pressure relationships assumed in this analysis. The specific forms of these relationships when peak overpressure is the independent variable are:

FIGURE 5

CONVERSIONS TO VALUE OF DAMAGE-DISTANCE SIGMA



a). Cumulative Log Normal

$$P_d(P) = \frac{1}{2\pi} \int_{-\infty}^{\frac{\ln\left(\frac{P}{P_{50}}\right)}{\beta_P}} \exp\left(-\frac{1}{2}y^2\right) dy \quad .$$

b). Cumulative Log Uniform

$$P_d(P) = 0 \qquad \frac{P}{P_{50}} < \frac{1}{a_P}$$

$$P_d(P) = \frac{1}{2 \ln a_P} \ln\left(\frac{a_P P}{P_{50}}\right) \qquad \frac{1}{a_P} \leq \frac{P}{P_{50}} \leq a_P$$

$$P_d(P) = 1.0 \qquad \frac{P}{P_{50}} > a_P \quad .$$

c). Cumulative Log Triangular

$$P_d(P) = 0 \qquad \frac{P}{P_{50}} < \frac{1}{c_P}$$

$$P_d(P) = \frac{1}{2 \ln^2 c_P} \ln^2\left(\frac{c_P P}{P_{50}}\right) \qquad \frac{1}{c_P} \leq \frac{P}{P_{50}} \leq 1$$

$$P_d(P) = 1 - \frac{1}{2 \ln^2 c_P} \ln^2\left(\frac{P}{c_P P_{50}}\right) \qquad 1 \leq \frac{P}{P_{50}} \leq c_P$$

$$P_d(P) = 1.0 \qquad \frac{P}{P_{50}} > c_P \quad .$$

The relationships when peak dynamic pressure is used as the independent variable are identical with the substitutions Q for P, Q_{50} for P_{50}, and Q rather than P as the subscripts for β, a, and c.

The key parameters of the probability of damage versus distance to the ground zero and probability of damage versus peak pressure relationships are related to one another in the following manner. For peak overpressures less than about 10 psi and peak dynamic pressures below roughly 2 psi, the peak pressure decreases with increasing distance from the ground zero in a manner than can be approximated by

$$P = k R^{-N}$$

where P is the peak pressure, R is the distance to the ground zero, and k and N are constants that depend on the yield, height-of-burst, and whether overpressure or dynamic pressure is being considered.

Using this approximation results in the following relationships between the parameters of the three damage laws considered in the study:

$$\beta_R = \frac{\beta_P}{N}$$

$$a_R = a_P^{1/N}$$

$$c_R = c_P^{1/N}$$

For the assumed yield and height-of-burst conditions of the Hiroshima and Nagasaki weapons, the values of N are:

Hiroshima Weapon	-	Overpressure $N = 1.60$
	-	Dynamic Pressure $N = 2.79$
Nagasaki Weapon	-	Overpressure $N = 1.57$
	-	Dynamic Pressure $N = 2.82$

compared to the values of $N = 1.67$ and $N = 3.42$ that are derived for surface bursts of weapons.

C. CONFIDENCE REGIONS

In addition to making point estimates of the key parameters of the probability of damage versus distance to the ground zero (or peak pressure) relationships using the Maximum Likelihood Estimate technique, confidence regions for the true values of these key parameters can be estimated from the basic damage-distance or damage-calculated peak pressure data. The technique requires, first, to define the variable

$$\lambda = \frac{L}{L_{MLE}}$$

where L_{MLE} is the value of the Likelihood Function (Equation (2)) using the Maximum Likelihood Estimate (M.L.E.) of the key parameters of the probability of damage relationship and L is the value of the Likelihood Function using some other values for the key parameters. By definition, $\lambda = 1$ at the maximum likelihood point (i.e., $L = L_{MLE}$). As the key parameters are varied from the MLE values, however, λ decreases, thus λ is defined over the range of parameter values $0 < \lambda \leq 1$. If an exact probability distribution for λ could be obtained, the confidence limits could be obtained easily using the cumulative distribution of λ. In this case, though an exact distribution cannot easily be obtained, a very good approximation does exist for this problem. A theorum of statistics states (see, for example, Reference 7) that

> "under certain conditions of regularity, the random variable $-2 \ln \lambda$ has a distribution that approaches that of a 'Chi Squared' variable as the number of data points in the sample becomes infinite, with its degrees of freedom equal to the number of parameters being determined by the hypothesis H."

Since all of the probability of damage relationships being considered in this analysis have two key parameters, the distribution function for the variable $-2 \ln \lambda$ is approximated by a "Chi Squared" distribution with two degrees of freedom, which is given by:

$$f(X^2) = \frac{1}{2} \exp\left(- \frac{1}{2} X^2 \right) .$$

The hypothesis (H) to be tested is that the true values of the key parameters of the probability of damage relationship are within some defined region that includes the Maximum Likelihood Estimates of these parameters. This becomes

$$\text{Probability H is True} = P\ (\lambda > \lambda_0) = \gamma = 1 - \alpha .$$

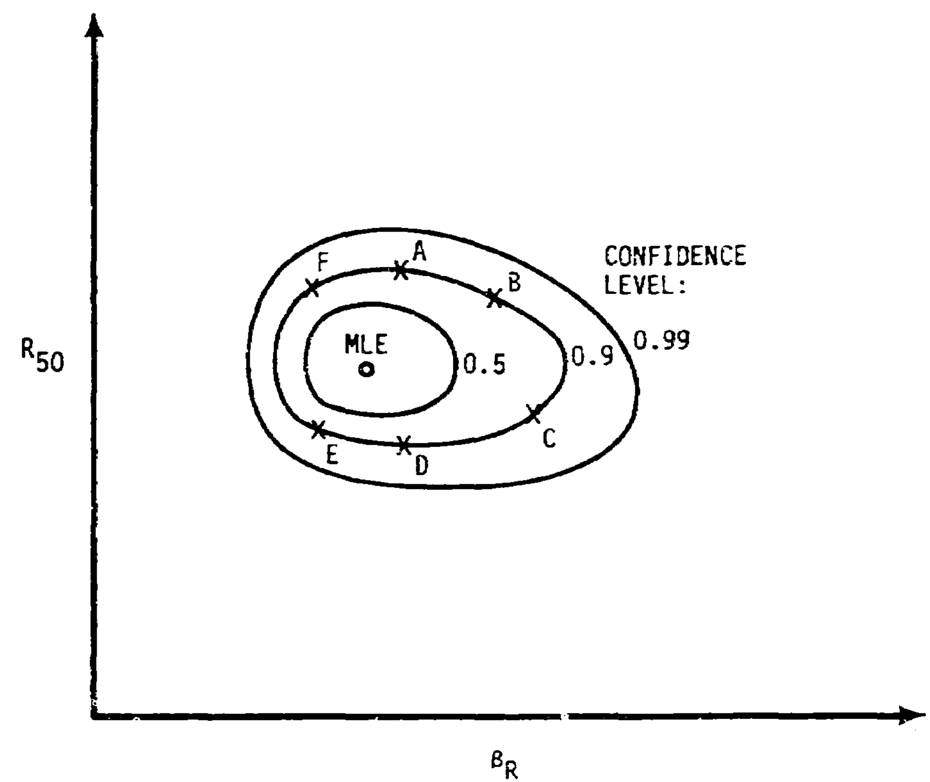
Since the distribution function for $-2 \ln \lambda$ is approximated by the two degree of freedom "Chi Squared" function, the confidence region for the key parameters is defined by the region where $\lambda > \lambda_0\ (=\alpha)$. For example, this means that the 0.9 confidence region (i.e., $\lambda = 0.9$) is defined by the region where $\lambda > \alpha = 0.1$.

The mechanical procedure used to find these confidence regions for the key parameters of the probability of damage relationships was to assume a fixed value for one of the key parameters in the probability of damage relationship and then to use the Newton-Ralphson method to determine the feasible solutions of the equation $\lambda - \alpha = 0$. This procedure was repeated using various assumed values of the same one of the key parameters in the probability of damage relationship until the entire confidence region was mapped.

The typical form of the confidence regions for the true values of R_{50} and β_R is illustrated in Figure 6. The regions always enclose the MLE values for the key parameters and grow larger as the confidence level is increased. The interpretation of these regions should be that given the particular data set that produced the MLE values of the key parameters of the probability of damage relationship, there is a given

FIGURE 6

TYPICAL FORM OF CONFIDENCE REGIONS
FOR TRUE VALUES OF R_{50} AND β_R



confidence level that the true values of these parameters lie within the enclosed region.

Uncertainty bounds for the probability of damage versus distance (or peak pressure) are also constructed using this type of diagram. The procedure used is to take various pairs of values of, for example, R_{50} and β_R and to construct the probability of damage (P_d) versus distance to the ground zero curves that result from these values. A bounding envelope that encompasses all possible values of P_d at fixed distances from the ground zero is then constructed. This bounding envelope then defines the uncertainty in the values of the probability of damage for a fixed confidence region.

In general, at values of P_d near 0.5, the bounding envelopes will be very close to the P_d versus R curves constructed using the R_{50}-β_R pairs denoted as A and D in Figure 6, which represent the largest and smallest values of R_{50} for a given confidence level. At low probabilities of damage, the bounding curves will be very near the values of P_d versus R curves produced using the R_{50}-β_R pairs denoted as B and E, i.e., large R_{50}-large β_R and small R_{50}-small β_R. At high probabilities of damage, the bounds will be near the P_d versus R curves using the pairs denoted as F and C, i.e., large R_{50}-small β_R and small R_{50}-large β_R. The envelope for other regions of the value of the probability of damage are derived by other R_{50}-β_R pairs that occur on the confidence region boundary.

[redacted]

V. ANALYSIS RESULTS

The Statistical Analysis efforts were oriented toward illuminating the following issues:

1). What is the "best" estimate of the value of the distance-damage sigma that can be made from the available data set for a given structure class and damage criteria? How uncertain is this estimate?

2). Does the "best" estimate of the value of the distance-damage sigma for a given structure class depend on the damage criteria?

3). Does subdivision of structure classes change the value of the distance-damage sigma?

4). Do the Japanese data support a perferred form of probability of damage versus distance (or pressure) relationship?

The results that provide insight into these issues will be summarized in the following discussions. Unless otherwise specified, these results will be based on the nominal assumptions of 12 Kt yield for the Hiroshima weapon and the Cumulative Log Normal Damage Law.

A. "BEST" ESTIMATE OF THE VALUE OF THE DISTANCE-DAMAGE SIGMA

The procedure used in determining the "best" estimate of the value of the distance-damage sigma (σ_d) utilized the technique of estimating the values of the standard deviations of the Cumulative Log Normal Damage Law (β_R or β_P) and then converting these values to values of σ_d utilizing the equations shown in Section IV of this report. This procedure involves using the methods shown in Section IV to calculate the following cases for each structure classification and damage criteria under consideration:

1. MLE values of the key parameters of the probability of damage versus distance relationships for the structures at Hiroshima.

2. MLE values of the key parameters of the probability of damage versus distance relationships for the structures at Nagasaki.

3. MLE values of the key parameters of the probability of damage versus calculated peak pressure relationships using the combined Hiroshima and Nagasaki data.

4. Confidence regions for the key parameters of the probability of damage versus calculated peak pressure relationships using the combined Hiroshima and Nagasaki data.

5. Confidence regions for the key parameters of the probability of damage versus distance relationships for the buildings at Hiroshima (calculated directly from the direct damage-distance data and inferred from the damage-calculated peak pressure data).

6. Confidence regions for the key parameters of the probability of damage versus distance relationships for the buildings at Nagasaki. (Again, both directly calculated and inferred values.)

Figures 7 through 11 illustrate the typical form of the results of these calculations for one structure classification and damage criteria using the Cumulative Log Normal Damage Law. The particular case shown is the Single-Story Masonry Load-Bearing-Wall Buildings and the Structural Damage Criteria.

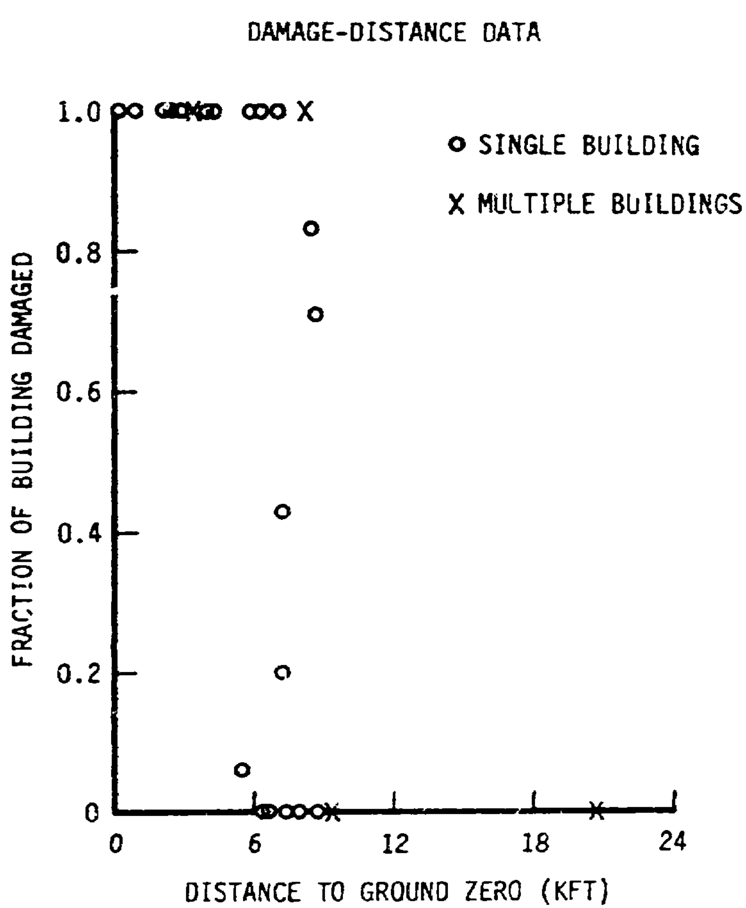
Figure 7 shows the effect of the value of the Specified Damage Fraction (SDF) on the MLE values of R_{50} and β_R for the Single-Story Masonry Load-Bearing-Wall Buildings at Hiroshima data set. The exhibited decrease in the value of R_{50} with increasing value of the SDF should be expected, since larger values of the SDF imply "harder" buildings. The MLE value of β_R varying by about 50 percent as the SDF goes for 0^+ to 1.0^- is, however, unexpected, since a non-constant value of β_R leads to the absurdity of having certain distances from the ground zero where the probability of damage for an SDF value of, say, 0.5 is less than the probability of damage with an SDF value of 1.0^-.

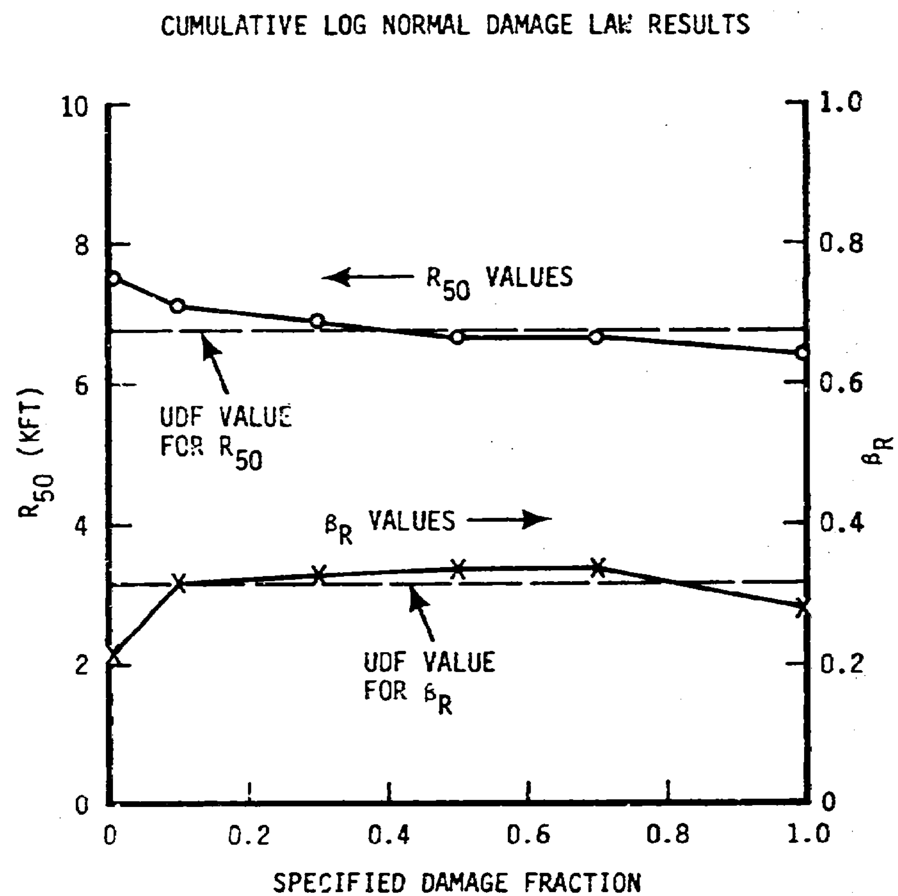
FIGURE 7

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. VALUES

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

STRUCTURAL DAMAGE CRITERIA





Also shown on the figure are the MLE values of R_{50} and β_R using the Unspecified Damage Fraction concept. Note that the UDF value of β_R is, for this data set, reasonably close to the SDF values of β_R for all values of the SDF except 0^+. This suggests that the UDF value of β_R may be a better estimate to the true value of β_R than any of the SDF values.

Figure 8 shows similar results, except dealing with the Nagasaki data set. For this data set, no values of the MLE can be defined for values of the SDF ≤ 0.4, since the buildings out to about 9000 feet from the ground zero are damaged according to the criteria and the buildings beyond about 11,000 feet from the ground zero are undamaged, and there are no data in the gap. For SDF values greater than 0.4, the building located 5300 feet from the ground zero with a fractional damage level of 0.4 is denoted as undamaged so that values of the MLE can be calculated.

The SDF and UDF values of R_{50} for this data set are somewhat higher than the values calculated from the Hiroshima data set but this should be expected since the Nagasaki weapon almost certainly had a higher yield than did the Hiroshima weapon.

The values of β_R are somewhat lower than the corresponding values for the Hiroshima data set. This is probably a result of the particular data points contained in the relatively poor Nagasaki data set, which has only four data points (at 8800 feet from the ground zero) that lie within roughly ± 1500 feet of the MLE estimates of R_{50}.

Figure 9 shows the effect of the value of the SDF on the values of P_{50} and β_P using the combined data set that results from converting the distance data into calculated peak pressure data with an assumed yield of 12 Kt for the Hiroshima weapon. The increase in P_{50} with increasing values of the SDF is to be expected, since an increase in the value of the SDF has the effect of making the buildings "harder." The roughly 40 percent variation in the value of the standard deviation is again not only unexpected but impossible, since the dependence of β_P on the value of the Specified Damage Fraction would lead to the same absurdities discussed with Figure 7. The data again suggest that the UDF value of β_P may be the best estimate of this parameter.

FIGURE 8

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. VALUES

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE CRITERIA

DAMAGE-DISTANCE DATA

CUMULATIVE LOG NORMAL DAMAGE LAW RESULTS

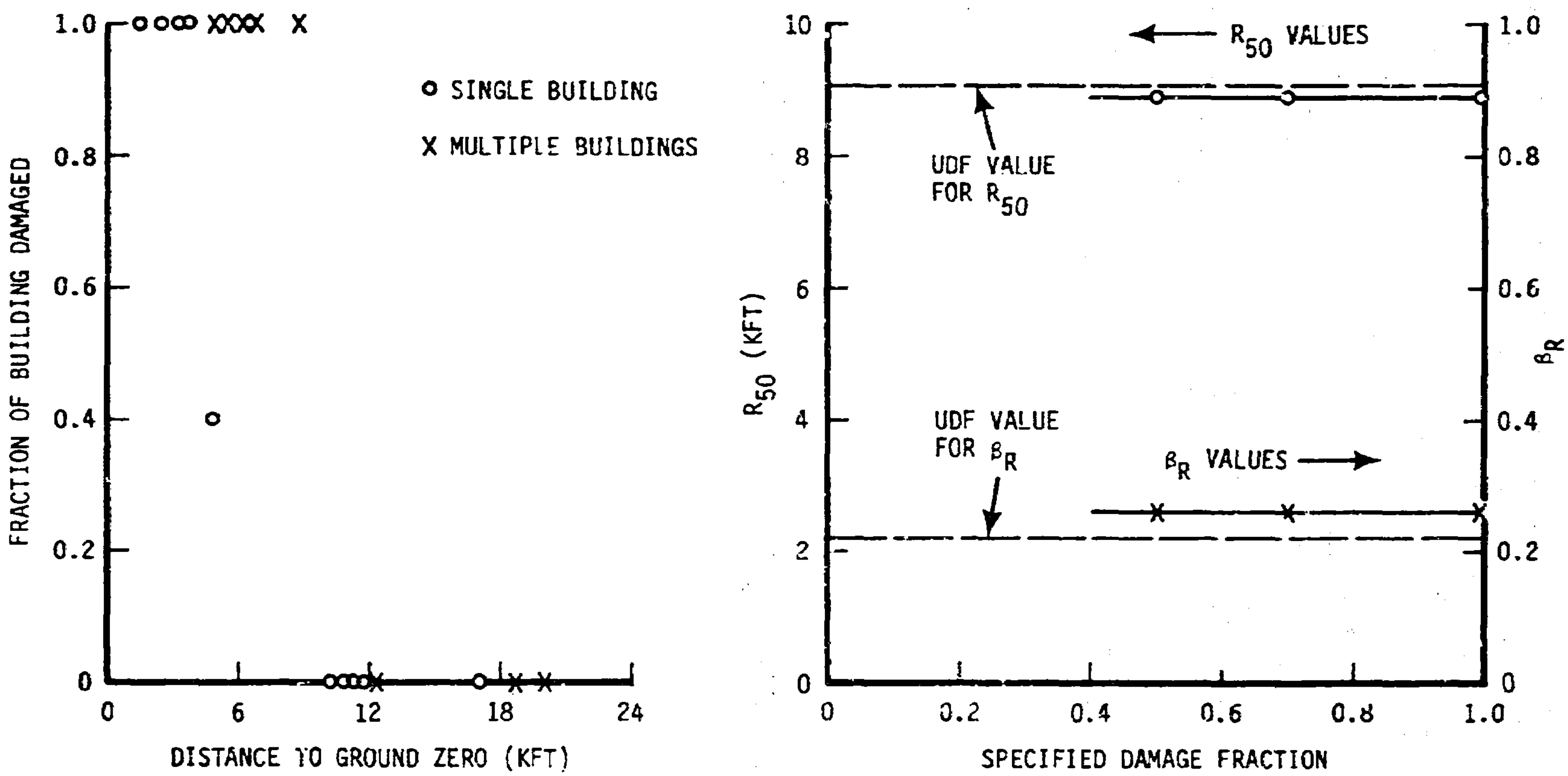


FIGURE 9

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. VALUES

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

STRUCTURAL DAMAGE CRITERIA

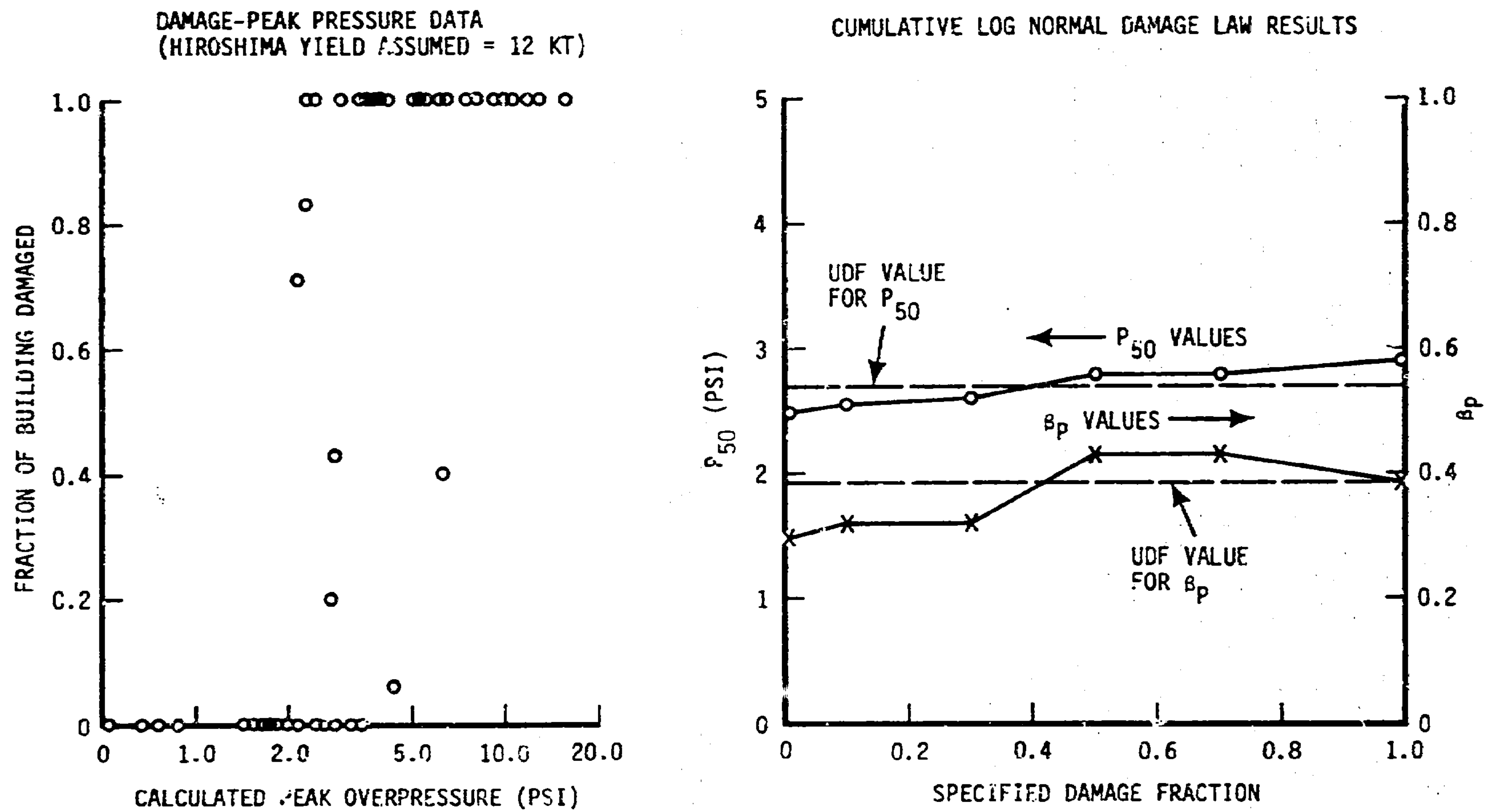


Figure 10 illustrates the confidence regions for the true values of P_{50} and β_P that are derived from the data set. Four cases are shown in the figure for SDF values of 0^+, 0.5, and 1.0^-, and the UDF values.

At the 0.5 confidence level, the maximum uncertainty in the true value of P_{50} is roughly ±10 percent of the Maximum Likelihood Estimate of P_{50}, while the uncertainty in the value of β_P is about a factor of 1.2 around the MLE values. At the 0.9 confidence levels, these uncertainties are roughly ±20 percent for the value of P_{50} and about a factor of 1.6 around the MLE for β_P.

It should also be noted that the MLE value of β_P, derived using the Unspecified Damage Fraction concept, is contained within the 0.9 confidence regions for all three values of the SDF shown in the figure. This further suggests that the MLE value of β_P (or β_R) using the UDF concept is the best estimate of the standard deviation that can be made from the data.

Figure 11 shows the confidence regions for the true values of R_{50} and β_R for the buildings at Hiroshima and the buildings at Nagasaki using the UDF concept. Two cases are shown for each city, the confidence regions derived from the direct use of the damage-distance data, and the confidence regions inferred from the damage-peak overpressure results shown in Figure 10. The inferred confidence regions are obtained by converting the combined damage-calculated peak pressure data back into damage-distance data using the appropriate yield and height-of-burst conditions for the city under consideration.

For the Hiroshima buildings, the uncertainty in the value of R_{50} and β_R derived from the damage-distance data is about a factor of 1.1 in terms of the MLE value of R_{50} and a factor of 1.5 in terms of the MLE value of β_R for the 0.5 confidence level. At the 0.9 confidence level, the corresponding uncertainty factors are 1.2 and 2.15, respectively. These large uncertainty regions for the true value of β_R are believed to be primarily due to the gaps in the Hiroshima data shown in Figure 7 for distances from the ground zero between roughly 10 and 20 Kft.

FIGURE 10

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

STRUCTURAL DAMAGE CRITERIA

- CUMULATIVE LOG NORMAL DAMAGE LAW
- HIROSHIMA YIELD ASSUMED = 12 KT

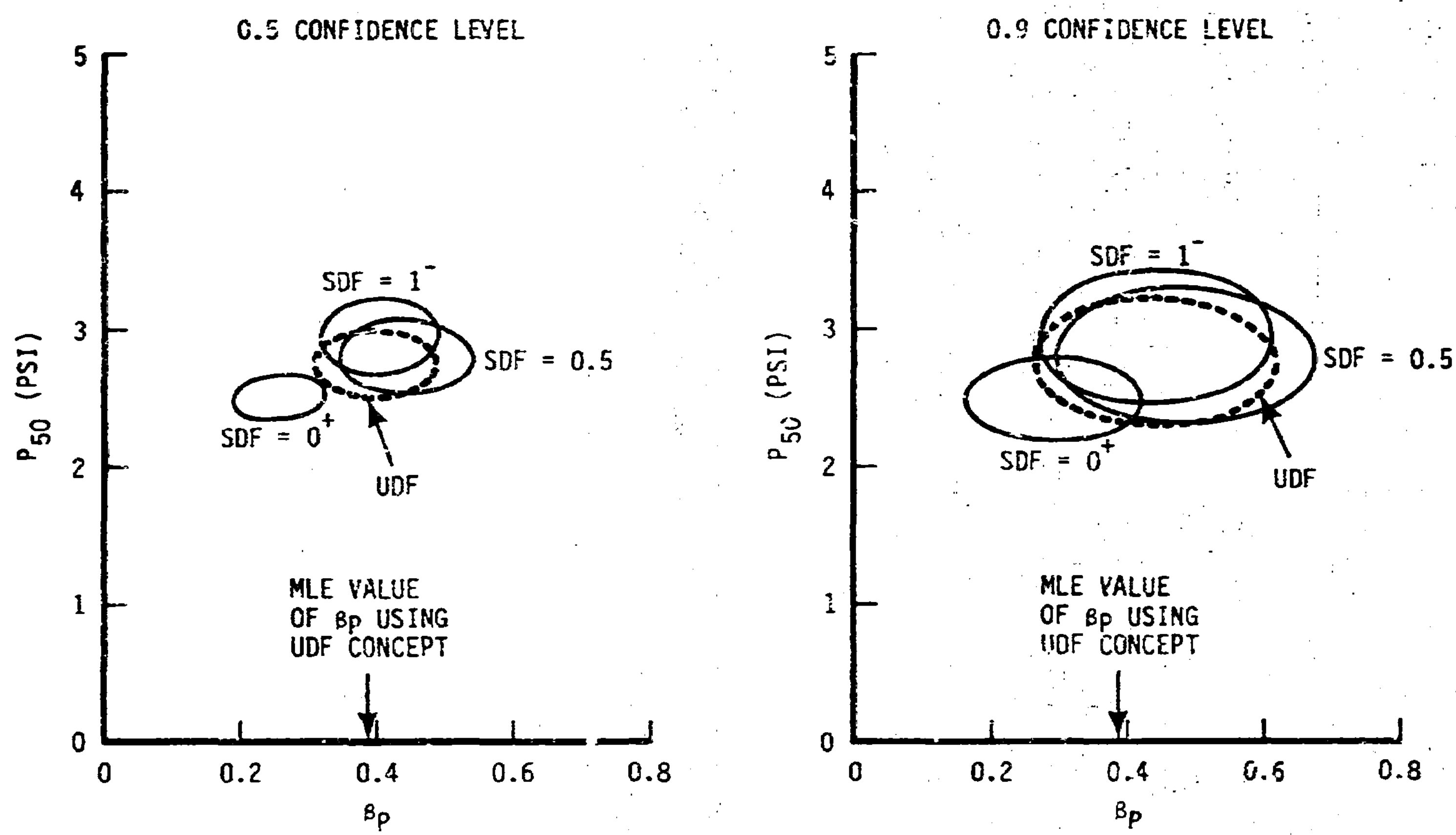


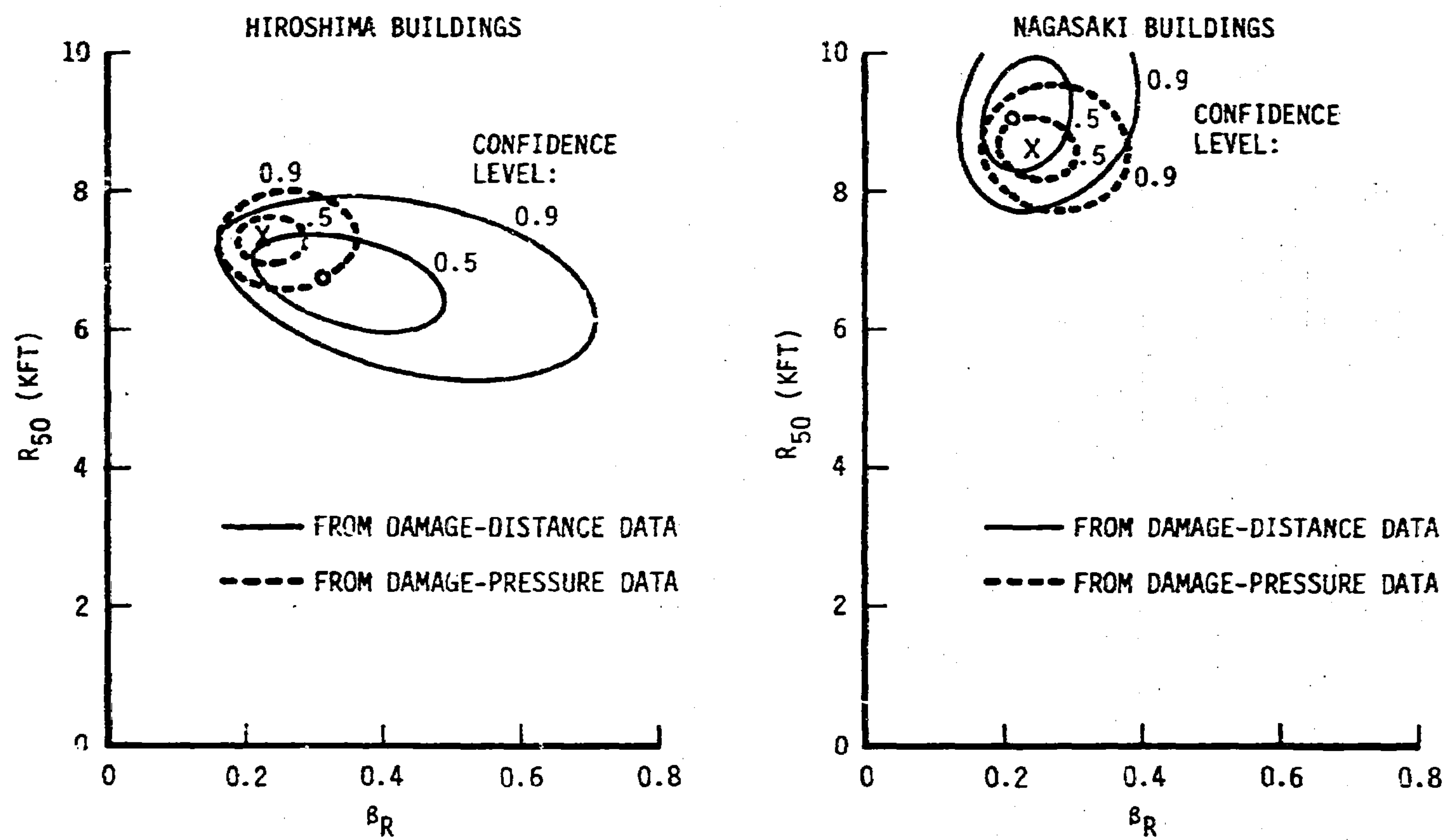
FIGURE 11

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

STRUCTURAL DAMAGE CRITERIA

- UNSPECIFIED DAMAGE FRACTION
- CUMULATIVE LOG NORMAL DAMAGE LAW
- HIROSHIMA YIELD ASSUMED = 12 KT



The confidence regions derived from the damage-distance data for the Nagasaki buildings give uncertainties in the true value of R_{50} that are similar in magnitude to those for the Hiroshima buildings. The uncertainties in the true value of β_R are, however, much smaller for the Nagasaki buildings than the values exhibited for the Hiroshima buildings.

For both the Hiroshima and Nagasaki buildings, the confidence regions inferred from the damage-calculated peak overpressure data combine with the regions derived from the damage-distance data to indicate that the true value of β_R for this case is most likely in the region between 0.2 and 0.3. In particular, it would appear that the value of $\beta_R = 0.236$ inferred from the MLE value of β_P for the Unspecified Damage Fraction concept is the best estimate of the parameter than can be made. This value of β_R then produces a "best" estimate of the value of the distance-damage sigma equal to 0.223. (It should be noted that if the Hiroshima and Nagasaki results represented two repetitions of a single experiment, which they do not, the best estimate of the value of β_R that could be made would be the average of the values for the two experiments, β_R = 0.268. This value is remarkably close to the value derived from the UDF value of β_P.)

Some insight on the relative yields of the Hiroshima and Nagasaki yields can also be gained from Figure 11. As can be seen in this figure, the MLE values of R_{50} inferred from the combined damage-calculated peak pressure data are somewhat higher, for Hiroshima, and somewhat lower, for Nagasaki, than the MLE values of R_{50} calculated directly from the damage-distance data for the individual cities. The R_{50} values for Hiroshima could be brought more into line by assuming a yield higher than 12 Kt for the Hiroshima weapon. (The value of P_{50} would increase, which would thus decrease R_{50}.) This, however, would cause a greater difference between the directly calculated and inferred-from calculated peak pressure values of R_{50} for Nagasaki. Similarly, the values of R_{50} for Nagasaki could be brought more into line by assuming a yield lower than 12 Kt for the Hiroshima weapon, but the values of R_{50} for Hiroshima would then be more divergent. Thus, this data set supports the yield assumption of about 12 Kt for the Hiroshima weapon.

The impact of the uncertainties in the values of R_{50} and β_R on the probability of damage versus distance relationship is illustrated in Figure 12 for the case of the assumed Hiroshima yield and height-of-burst conditions and a Specified Damage Fraction of 0.5. The nominal values of probability of damage versus distance are derived from the Cumulative Log Normal Damage Law using the best estimate values of R_{50} and β_R derived from the damage-calculated peak overpressure data. The bounds on the probability of damage values represent the envelopes that enclose all the potential values of probability of damage at a given distance that are calculated using the R_{50}-β_R pairs that occur on the bounds of the 0.5 or 0.9 confidence regions for this data set.

The 0.5 confidence level bounds indicate uncertainties in the distance to the ground zero for a fixed probability of damage of about 1000 feet for high probabilities of damage (~0.9) and about 2000 feet at low probabilities of damage (~0.1). These uncertainties represent roughly ±10 percent of the distance to the ground zero for a given probability of damage using the nominal Pd versus distance to the ground zero relationships.

The 0.9 confidence level bounds indicate uncertainties in the distance to the ground zero for a fixed probability of damage that are about twice the magnitude of those for the 0.5 confidence level. Thus, the uncertainty in the distance to the ground zero is about ±20 percent of the nominal distance at this confidence level.

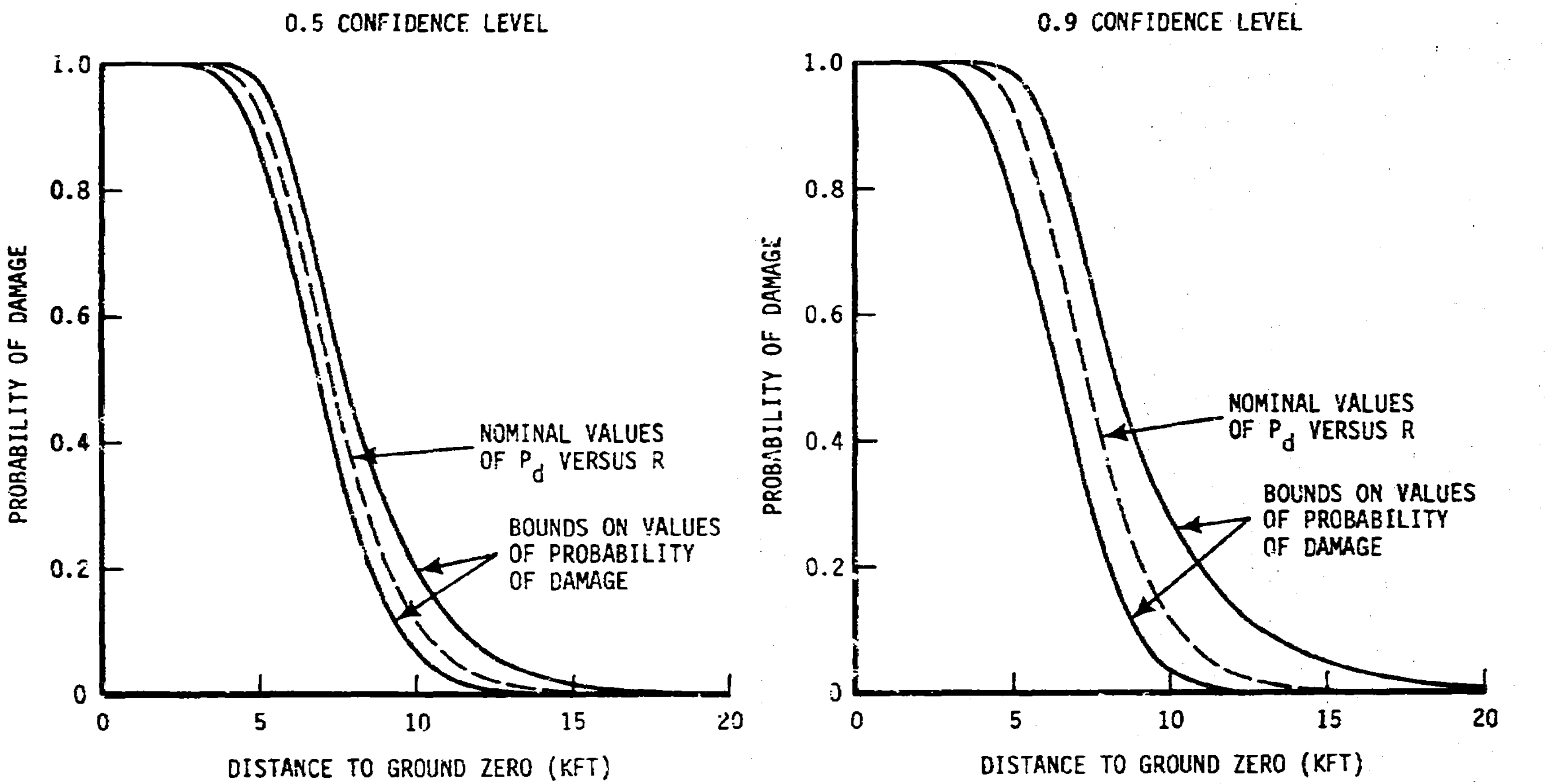
Another way of considering the impact of these uncertainties is to consider the bounding values in the probability of damage at a fixed distance from the ground zero. At the distance where the nominal probability of damage is 0.1, the bounding values of Pd for the 0.5 confidence level vary by a factor of about 1.8 around the nominal value. At the 0.9 confidence level, the bounding values vary by about a factor of 2.6 around the nominal value of 0.1.

FIGURE 12

UNCERTAINTIES IN PROBABILITY OF DAMAGE RELATIONSHIP FOR HIROSHIMA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

- STRUCTURAL DAMAGE CRITERIA (SDF = 0.5)
- CUMULATIVE LOG NORMAL DAMAGE LAW
- DERIVED FROM PRESSURE RESULTS (HIROSHIMA YIELD = 12 KT)



Turning next to the effect of the forms of the probability of damage versus distance relationship, Figure 13 compares the probability of damage values that result from the "best" fits to the data of each of the three damage laws considered in the analysis for the case of Structural Damage and the Single-Story Masonry Load-Bearing-Wall Buildings. The results are shown for the Hiroshima height-of-burst conditions and an assumed yield of 12 Kt, and are derived from the "best" estimates of the key parameters of the probability of damage relationships when calculated peak overpressure is used as the mechanism to combine the Hiroshima and Nagasaki data.

As can be seen, the resulting values of probability of damage for the Cumulative Log Normal and the Cumulative Log Triangular Damage Laws are quite similar, while the values of the probability of damage produced by the Cumulative Log Uniform Damage Law are almost always lower than the values produced by the other damage laws. The values of the distance-damage sigma for the three damage laws are, however, remarkably similar, ranging from about 0.23 to 0.26. This suggests that the value of the distance-damage sigma may be essentially independent of the form of the damage law.

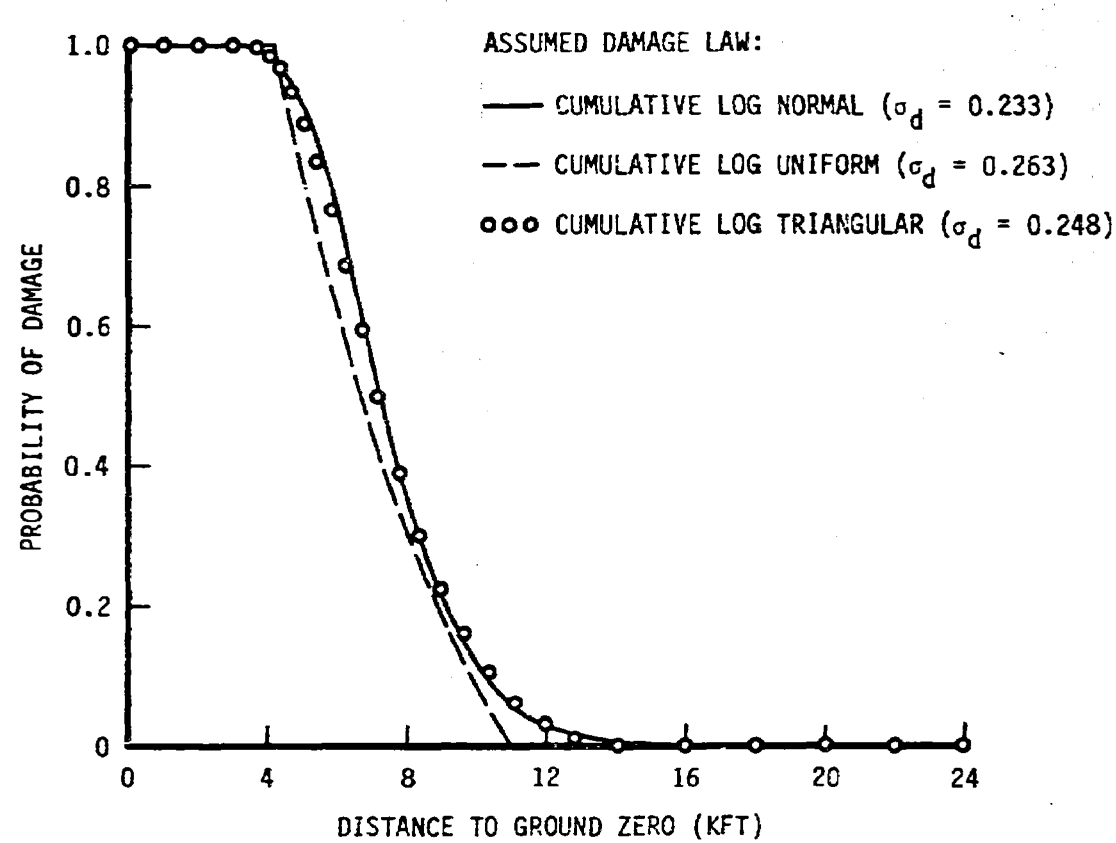
There are, however, more subtle differences between the results than can be observed from the graph. The probability of damage values produced by the Cumulative Log Triangular Damage Law are absolute unity for distances to the ground zero of less than 3.66 Kft and are absolute zero for distances to the ground zero greater than 14.05 Kft. The probability of damage values produced by the Cumulative Log Normal distribution only asymptotically approach these values as the distance to the ground zero approaches zero and infinity, respectively.

FIGURE 13

COMPARISON OF DAMAGE RELATIONSHIPS FOR HIROSHIMA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

- STRUCTURAL DAMAGE CRITERIA (SDF = 0.5)
- DERIVED FROM PRESSURE RESULTS (HIROSHIMA YIELD = 12 KT)



Applying statistical tests, such as "Goodness of Fit," to the three probability of damage relationships provides very little insight as to the "correct" form of the probability of damage relationship. For the case shown in Figure 13, the Cumulative Log Normal and Cumulative Log Triangular Damage Laws, according to the "Goodness of Fit" test, provide slightly better fits to the data than does the Cumulative Log Triangular Damage Law. The results, however, are not sufficiently different so as to reject the Cumulative Log Uniform Damage Law.

B. EFFECT OF STRUCTURE CLASS AND DAMAGE CRITERIA ON THE "BEST" ESTIMATE OF THE VALUE OF THE DISTANCE-DAMAGE SIGMA

Previous analyses of the Japanese structural damage data have used the TM-4 data base, which considers only the Structural Damage criteria. These analyses concluded that the value of the distance-damage sigma depended primarily on whether the structure class under consideration was denoted as primarily sensitive to overpressure effects or dynamic pressure effects. Single-story and Multistory Masonry Load-Bearing-Wall Buildings and Wood Frame Buildings were denoted as primarily sensitive to overpressure effects and were assigned the value of $\sigma_d = 0.2$. Single-Story Steel Frame Buildings were denoted as being primarily sensitive to dynamic pressure effects and assigned the value of $\sigma_d = 0.3$.

Table 5 shows the effect of structure class and damage criteria on the "best" estimate values of mean peak pressure required for a 0.5 probability of damage (P_{50} or Q_{50}) and the distance-damage sigma (σ_d) using the data base compiled in this study. The values for the Structural Damage criteria are derived using either calculated peak overpressure or calculated peak dynamic pressure, depending on the commonly denoted principal sensitivity of the structure class. The values for the Superficial Damage criteria are all derived assuming calculated peak overpressure as the primary damage correlating mechanism.

TABLE 5

EFFECT OF DAMAGE CRITERIA ON MLE VALUES OF MEAN PEAK PRESSURE AND σ_d

- Cumulative Log Normal Damage Law
- Specified Damage Fraction = 0.5
- Hiroshima Yield Assumed = 12 Kt

STRUCTURE CLASSIFICATION	STRUCTURAL DAMAGE CRITERIA		SUPERFICIAL DAMAGE CRITERIA	
SINGLE-STORY MASONRY LOAD-BEARING-WALL	$P_{50} = 2.77$	$\sigma_d = 0.233$	$P_{50} = 2.14$	$\sigma_d = 0.239$
MULTISTORY MASONRY LOAD-BEARING-WALL	$P_{50} = 3.26$	$\sigma_d = 0.104$	$P_{50} = 2.45$	$\sigma_d = 0.113$
SINGLE-STORY WOOD FRAME	$P_{50} = 1.80$	$\sigma_d = 0.345$	$P_{50} = 1.51$	$\sigma_d = 0.269$
MULTISTORY WOOD FRAME	$P_{50} = 2.41$	$\sigma_d = 0.093$	$P_{50} = 2.02$	$\sigma_d = 0.105$
SINGLE-STORY LIGHT STEEL FRAME	$Q_{50} = 0.47$	$\sigma_d = 0.390$	$P_{50} = 1.88$	$\sigma_d = 0.229$
SINGLE-STORY HEAVY STEEL FRAME	$Q_{50} = 0.45$	$\sigma_d = 0.293$	$P_{50} = 2.49$	$\sigma_d = 0.381$

For three of the structure classes, i.e., Single-Story and Multistory Masonry Load-Bearing-Wall Buildings and Multistory Wood Frame Buildings, the estimated values of the distance-damage sigma are essentially identical for both damage criteria. For the remaining three cases, however, the estimated value of the distance-damage sigma differs quite widely between the two damage criteria. (It should be noted that the differences between the values of σ_d for the Steel Frame Buildings is not due to using dynamic pressure for the Structural Damage case and overpressure for the Superficial Damage case. The value of σ_d calculated for the Superficial Damage criteria using dynamic pressure is within a few percent of being the same as the values shown in the table, which are calculated using calculated peak overpressure.)

This difference between the value of σ_d for the two different damage criteria within the same structure class is of great significance, since the Superficial Damage criteria is an "at least" type of criteria that includes Structural Damage within its definition. The Cumulative Log Normal Damage Law has the property that two probability of damage versus distance (or pressure) curves having different values for the distance-damage sigma will cross at some value of distance (or pressure). This will then result in having regions where the calculated probability of Structural Damage is greater than the calculated probability of Superficial Damage.

This, of course, is an absurdity. The probability of at least Superficial Damage must always be equal to or greater than the probability of Structural Damage. Therefore, the existence of the significantly different values of the distance-damage sigma for the two damage criteria would make the Cumulative Log Normal Damage Law suspect unless the data set is poor (i.e., gaps in the data or few buildings new R_{50}).

The smaller values of the distance-damage sigma for Multistory compared to Single-Story Buildings of the same general class may cast further doubts as to the validity of the Cumulative Log Normal Damage Law. The Multistory Buildings, as a class, are harder than the Single-Story

Buildings. Yet the significantly smaller values of σ_d for the Multistory Buildings would result in regions where the probability of damage for the Single-Story Buildings would be less than the probability of damage for the Multistory Buildings. This would require that, say, some Single-Story Wood Frame Buildings be harder than all of the Multistory Masonry Load-Bearing-Wall Buildings. This is supported by the data in the case of the Japanese structures but may not be the case for other structure classifications.

Overall, these difficulties with the Cumulative Log Normal Damage Law could be resolved if the value of the distance-damage sigma were a universal constant independent of damage criteria and structure classification. This does not appear to be the case based on the point estimates of σ_d derived for the Japanese Structural Damage data.

The Cumulative Log Uniform and Cumulative Log Triangular Damage Laws avoid some of the difficulties encountered with the Cumulative Log Normal Damage Law. The value of the distance-damage sigma need not be identical for Structural and Superficial Damage criteria, although there are certain restrictions on the relative values. Similarly, within certain restrictions, the Multistory Buildings can have different values of the distance-damage sigma than do the Single-Story Buildings without encountering potential difficulties.

Table 6 shows the values of the median peak pressure required for a 0.50 probability of damage and the value of the damage-distance sigma derived for the Structural and Superficial Damage criteria using the Cumulative Log Uniform Damage Law. In general, the values of σ_d are quite similar to those derived using the Cumulative Log Normal Damage Law, the values for Superficial Damage to Single-Story Masonry Load-Bearing-Wall and Single-Story Light Steel Frame Buildings being somewhat higher for the Cumulative Log Uniform Damage Law.

It is also interesting to note that the values of the mean peak pressure required are somewhat higher for the Masonry Load-Bearing-Wall and Wood Frame Buildings, while all other mean peak pressures required are somewhat lower than those derived using the Cumulative Log Normal Damage Law.

TABLE 6

EFFECT OF DAMAGE CRITERIA ON MLE VALUES OF MEAN PEAK PRESSURE AND σ_d

- Cumulative Log Uniform Damage Law
- Specified Damage Fraction = 0.5
- Hiroshima Yield Assumed = 12 Kt

STRUCTURE CLASSIFICATION	STRUCTURAL DAMAGE CRITERIA		SUPERFICIAL DAMAGE CRITERIA	
SINGLE-STORY MASONRY LOAD-BEARING WALL	$P_{50} = 3.15$	$\sigma_d = 0.263$	$P_{50} = 1.96$	$\sigma_d = 0.317$
MULTISTORY MASONRY LOAD-BEARING WALL	$P_{50} = 3.64$	$\sigma_d = 0.097$	$P_{50} = 2.53$	$\sigma_d = 0.117$
SINGLE-STORY WOOD FRAME	$P_{50} = 1.97$	$\sigma_d = 0.346$	$P_{50} = 1.42$	$\sigma_d = 0.344$
MULTISTORY WOOD FRAME	$P_{50} = 2.51$	$\sigma_d = 0.140$	$P_{50} = 1.99$	$\sigma_d = 0.150$
SINGLE-STORY LIGHT STEEL FRAME	$Q_{50} = 0.44$	$\sigma_d = 0.382$	$P_{50} = 1.86$	$\sigma_d = 0.384$
SINGLE-STORY HEAVY STEEL FRAME	$Q_{50} = 0.37$	$\sigma_d = 0.346$	$P_{50} = 1.93$	$\sigma_d = 0.436$

Table 7 shows the effect of the damage criteria when the Cumulative Log Triangular Damage Law is used to derive the values of the mean peak pressure required for a 0.5 probability of damage and the distance-damage sigma. While there are restrictions on the variation in values of the distance-damage sigma with damage criteria for each structure class, the values of σ_d shown in the table for each structure class fall within acceptable limits. Indeed, except for the case of the Heavy Steel Frame Buildings, the value of σ_d is fairly independent of the damage criteria.

Comparison of the values of the mean peak pressure (P_{50} or Q_{50}) shown in this table with the values derived using the Cumulative Log Normal Damage Law (Table 5) shows the values to be nearly identical for every damage criteria and structure class. Comparison of the values of the distance-damage sigma also show that with two exceptions (Superficial Damage to Single-Story Masonry Load-Bearing-Wall Buildings and Light Steel Frame Buildings) the estimated values of the distance-damage sigma are essentially independent of whether the Cumulative Log Normal or the Cumulative Log Uniform Damage Law is used to estimate its value.

Overall, the results of this investigation of the effect of damage criteria indicate that the value of the distance-damage sigma for a given structure class <u>may</u> not be independent of the damage criteria. If this is indeed true, use of the Cumulative Log Normal Damage Law will result in absurdities in that the calculated probability of Structural Damage will be higher than the calculated probability of Superficial Damage over some distance (or pressure) region. The Cumulative Log Uniform and Cumulative Log Triangular Damage Laws can avoid this problem but neither can be accepted or rejected on the basis of the available evidence.

C. SUBCLASSIFICATION OF MAJOR STRUCTURE CLASSES

The buildings in the data base belonging to any one particular major structure class have a great deal of variability in terms of construction characteristics. Considering the 101 Single-Story Masonry Load-Bearing-Wall Buildings, 14 have walls between 7 and 9 inches thick, 28

TABLE 7

EFFECT OF DAMAGE CRITERIA ON MLE VALUES OF MEAN PEAK PRESSURE AND σ_d

- Cumulative Log Triangular Damage Law
- Specified Damage Fraction = 0.5
- Hiroshima Yield Assumed = 12 Kt

STRUCTURE CLASSIFICATION	STRUCTURAL DAMAGE CRITERIA		SUPERFICIAL DAMAGE CRITERIA	
SINGLE-STORY MASONRY LOAD-BEARING-WALL	$P_{50} = 2.87$	$\sigma_d = 0.248$	$P_{50} = 2.08$	$\sigma_d = 0.288$
MULTISTORY MASONRY LOAD-BEARING-WALL	$P_{50} = 3.22$	$\sigma_d = 0.102$	$P_{50} = 2.47$	$\sigma_d = 0.112$
SINGLE-STORY WOOD FRAME	$P_{50} = 1.82$	$\sigma_d = 0.330$	$P_{50} = 1.48$	$\sigma_d = 0.299$
MULTISTORY WOOD FRAME	$P_{50} = 2.43$	$\sigma_d = 0.107$	$P_{50} = 2.02$	$\sigma_d = 0.122$
SINGLE-STORY LIGHT STEEL FRAME	$Q_{50} = 0.46$	$\sigma_d = 0.376$	$P_{50} = 1.90$	$\sigma_d = 0.323$
SINGLE-STORY HEAVY STEEL FRAME	$Q_{50} = 0.43$	$\sigma_d = 0.291$	$P_{50} = 2.34$	$\sigma_d = 0.403$

have walls between 12 and 14 inches thick, 12 have walls between 17 and 19 inches thick, 5 have walls between 23 and 27 inches thick, while the remaining 42 buildings have walls of unknown thickness. The roof construction details show that 5 of these buildings have reinforced concrete roofs, 33 have steel roof trusses, 59 have wood roof trusses, and the roof construction of the remaining four buildings is unknown. Of the 92 buildings with steel or wood roof trusses, 22 have corregated asbestos roof covers, while the remaining 70 have roof cover materials such as corregated iron, tile on wood, etc.

In view of this veritable "hodge-podge" of construction characteristics, the question naturally arises as to whether the values of the distance-damage sigma (σ_d) might not be significantly smaller for more closely defined structure classifications and damage criteria. To investigate this matter, each of the major structure categories was subdivided according to the characteristics that were believed to have the major influence on the results for the damage criteria being considered. The details of this investigation are contained in Appendix B. These results will be summarized, by major structure class, in the next few paragraphs.

Table 8 summarizes the results of considering structure subclassifications for the Masonry Load-Bearing-Wall Buildings in the data base in terms of the values of the peak overpressure for a 0.5 probability of damage (P_{50}) and the distance-damage sigma (σ_d) derived assuming the Cumulative Log Normal Damage Law. For the Single-Story Buildings, there appears to be both reductions and increases in the value of σ_d with structure subclassification. While the relative values of P_{50} within the subclassifications all are in sensible directions, the changes in the estimated value of σ_d are, however, probably an illusion. The confidence regions for the key parameters of the probability of damage relationship (shown in Appendix B) are, in all cases, large enough to support the hypothesis that the value of the distance-damage sigma is independent of the structural subclassifications and damage criteria.

TABLE 8

EFFECT OF SUBCLASSIFICATION ON VALUE OF σ_d

Masonry Load-Bearing-Wall Buildings

- Specified Damage Fraction = 0.5
- Hiroshima Yield Assumed = 12 Kt

DAMAGE CRITERIA	STRUCTURE SUBCLASSIFICATION	P_{50} (PSI)/σ_d SINGLE-STORY BUILDINGS	P_{50} (PSI)/σ_d MULTISTORY BUILDINGS
STRUCTURAL	None	2.77/0.233	3.26/0.104
STRUCTURAL TO WALLS	None	3.50/0.260	4.30/0.083
	7" to 14" Thick Walls	3.11/0.302	
	17" to 27" Thick Walls	4.35/0.149	
STRUCTURAL TO ROOFS	None	2.77/0.256	3.26/0.105
	Steel Roof Trusses	3.45/0.266	
	Wood Roof Trusses	2.45/0.218	
SUPERFICIAL	None	2.14/0.239	2.45/0.113
	Roof Cover Material Fails Slowly	2.18/0.292	
	Roof Cover Material Fails Quickly	1.79/0.113	

A consistently smaller value of σ_d for the Multistory Buildings than for the Single-Story Buildings is exhibited for all of the cases shown in Table 8. Inspection of the basic damage-distance data for the Multistory Buildings, however, indicates that this is probably created by the particular distances from the ground zero where data points exist. All of the Multistory Masonry Load-Bearing-Wall buildings at Nagasaki are at least 11,000 feet from the ground zero and none are damaged according to any damage criteria. The 33 buildings at Hiroshima are in the region from 1000 to 10,000 feet from the ground zero, but only four buildings are in the region from 5000 to 8000 feet which contains the estimated value of R_{50} plus roughly one standard deviation on each side of the value of R_{50} for any of the damage criteria considered. The lower estimated values of σ_d for the Multistory Buildings must therefore be considered to be suspect.

The Structural Damage criteria is an either/or type criteria in that it involves the maximum of the Structural Damage to either the walls or the roof of a building. According to the "combined effects" methodology of Reference 8, if the Cumulative Log Normal Damage Law applies for Structural to Walls and Structural to Roofs Damage criteria, then the damage law for the Structural Damage criteria should be only approximately Log Normal with a value of P_{50} less than the smaller of the P_{50}'s for the Wall and Roof criteria and a value of the distance-damage sigma that is less than the larger of the σ_d's for the Wall and Roof criteria. Using this methodology and the values shown in Table 8 for Roof and Wall damage to the Single-Story Buildings gives calculated values of P_{50} and σ_d for the Structural Damage criteria that are within about 12 percent and 3 percent, respectively, of the values of P_{50} and σ_d shown in the table. This indicates that the Cumulative Log Normal Damage Law is at least approximately correct.

One other point to notice is that the values of P_{50} and σ_d for the cases of no structure subclassification are intermediate between the values for the corresponding subclassifications. In particular, the values of P_{50} and σ_d for the cases of no structure subclassification differ at most by a few

percent from the weighted logarithmic average of the values for the subclassifications. While no particular meaning can be attached to this observation, it is, however, indicative of how the Maximum Likelihood Estimate technique treats obvious mixtures of structure subclassifications.

Table 9 summarizes the results of the subclassification efforts for the Wood Frame Buildings. For this structure classification, there are, at most, moderate changes in the value of the distance-damage sigma for either the Single-Story or the Multistory Buildings. There is, however, the marked difference between the values of σ_d for Single-Story and Multistory Buildings.

At first sight, one might suspect that the significantly lower values of σ_d for the Multistory Buildings are probably due to poor data sets, as was the probable case with the Masonry Load-Bearing-Wall Buildings. Examining the locations of the various data points, however, reveals that this is not true, particularly when the Hiroshima and Nagasaki data are combined through the mechanism of calculated peak overpressure.

Examination of the individual data sheets for these buildings shows that 12 of the 22 buildings at Hiroshima and 15 of the 41 buildings at Nagasaki are school buildings with quite similar dimensions and construction details. The locations of these 27 school buildings relative to the ground zeros are also such that the damage to these buildings dominates the estimated values of P_{50} and σ_d for all of the damage criteria. Therefore, it appears that the results for the Multistory Wood Frame Buildings might more properly be called the results for Multistory Wood Frame Japanese School Buildings. The estimated value of the distance-damage sigma for this class of buildings is about one-third the value estimated for the general class of Single-Story Wood Frame Buildings.

TABLE 9

EFFECT OF SUBCLASSIFICATION ON VALUE OF σ_d

Wood Frame Buildings

- Specified Damage Fraction = 0.5
- Hiroshima Yield Assumed = 12 Kt

		P_{50} (PSI)/σ_d	
DAMAGE CRITERIA	STRUCTURE SUBCLASSIFICATION	SINGLE-STORY BUILDINGS	MULTISTORY BUILDINGS
STRUCTURAL	None	1.80/0.345	2.41/0.093
	Normal Walls-Wood Roof Trusses-Roof Cover Material Fails Slowly	1.75/0.308	2.35/0.118
STRUCTURAL TO ROOFS	None	1.81/0.367	2.41/0.089
	Wood Roof Trusses	1.70/0.381	---
SUPERFICIAL	None	1.50/0.269	2.02/0.105
	Roof Cover Material Fails Slowly	1.55/0.253	2.00/0.127
	Roof Cover Material Fails Quickly	1.30/0.293	---

Although the subclassification efforts for the Single-Story Wood Frame Buildings did not produce startling reductions in the estimated values of the distance-damage sigma, the magnitude of the values of σ_d and the difference between the value of σ_d for the Structural and the Superficial Damage criteria do merit further elaboration. This requires consideration of the basic damage-distance data for this structure class.

Figure 14 shows the basic fraction of the building damaged versus distance to the ground zero data contained in the data base for the Structural Damage criteria. The differences between the fraction of the buildings damaged at the same distances from the ground zero for the two data sets are quite striking and would almost suggest that the yield of the Hiroshima weapon must have been greater than the yield of the Nagasaki weapon, since fraction of the building damaged levels of unity occur out to roughly 13,000 feet from the ground zero for the Hiroshima data compared to about 9000 feet from the ground zero for the Nagasaki data. The hypothesis of a greater yield for the Hiroshima weapon, however, must almost certainly be rejected.

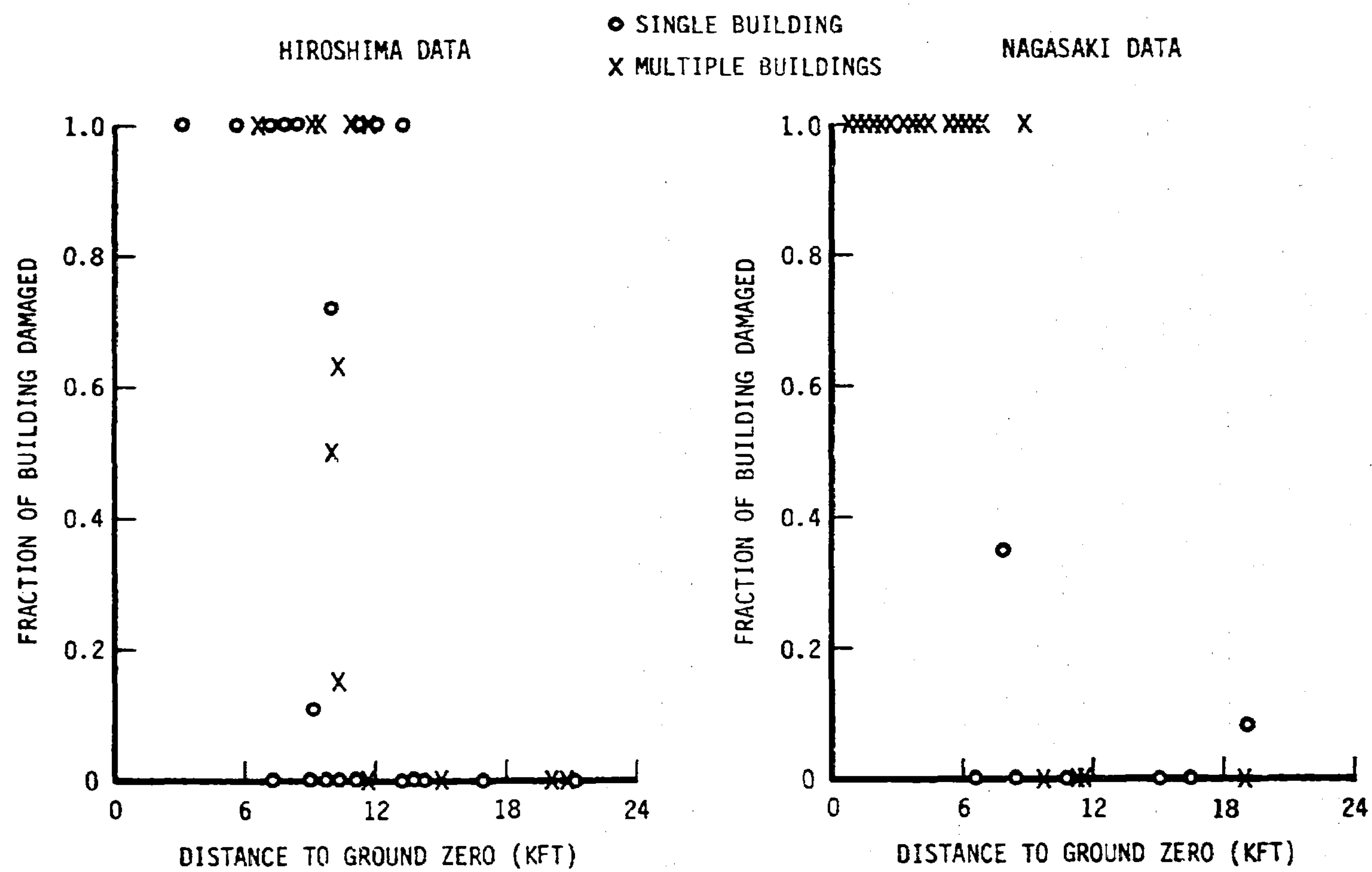
The Nagasaki data point located 19,000 feet from the ground zero with a fraction of the building damaged of 0.08 is of considerable interest. This building was denoted by the Strategic Bombing Survey Group (Reference 2) as being the farthest building from the ground zero at Nagasaki at which structural damage occurred. The Manhattan Engineering District Report (Reference 5), however, states:

> "The most impressive long-range damage was the collapse of some barrack sheds at Kamigo, 23,000 feet south of X in Nagasaki. It was remarkable to see some buildings intact to the last detail, including the roof and even the windows, yet next to them a similar building collapsed to ground level."

FIGURE 14

DAMAGE-DISTANCE DATA FOR STRUCTURAL DAMAGE CRITERIA

SINGLE-STORY WOOD FRAME BUILDINGS



Several questions arise from these conflicting statements. Primary among these are: a). Was the damage at Kamigo caused by the blast wave from the atomic bomb or was it caused by conventional HE bombs? (There is a very large difference between American sources and Japanese sources on the amount of conventional HE bombs dropped on Nagasaki during the war.) b). If the damage was caused by the atomic bomb, why were the results not included in the Strategic Bombing Survey results? (The survey team at Nagasaki did a very thorough on-site survey and report on the non-damage of structures that were within about one-half to three-quarters of a mile of Kamigo.) And, c). How many of the buildings at Kamigo were damaged and how many were undamaged?

The Strategic Bombing Survey Notes and Working Papers that are contained in the National Archives were searched in an attempt to answer these questions. The only conformation found that confirmed the qualitatively reported damage at Kamigo was a sketch map that was prepared by the Nagasaki Police Department about a week after the detonation of the weapon.* Kamigo is included in the area denoted as "damaged by blast." Checking buildings with known damage levels that lie within this area, however, indicates that the limits of the "damaged by blast" area were probably based on damage to window glass.

The damage-distance to the ground zero data for the Superficial Damage criteria is shown in Figure 15. The extreme distances from the ground zero at Hiroshima where Superficial Damage occurs (i.e., 20 to 22,000 feet) further reinforces the doubts about the Nagasaki data set. The occurrence of damage this far from the ground zero at Hiroshima certainly suggests that at least some Superficial Damage should have occurred at similar distances from the ground zero at Nagasaki if buildings of this type were present, of which there apparently were some.

Overall, the Nagasaki data set for the Single-Story Wood Frame Buildings must be viewed as suspect. It is, however, the best that can be obtained from the available records.

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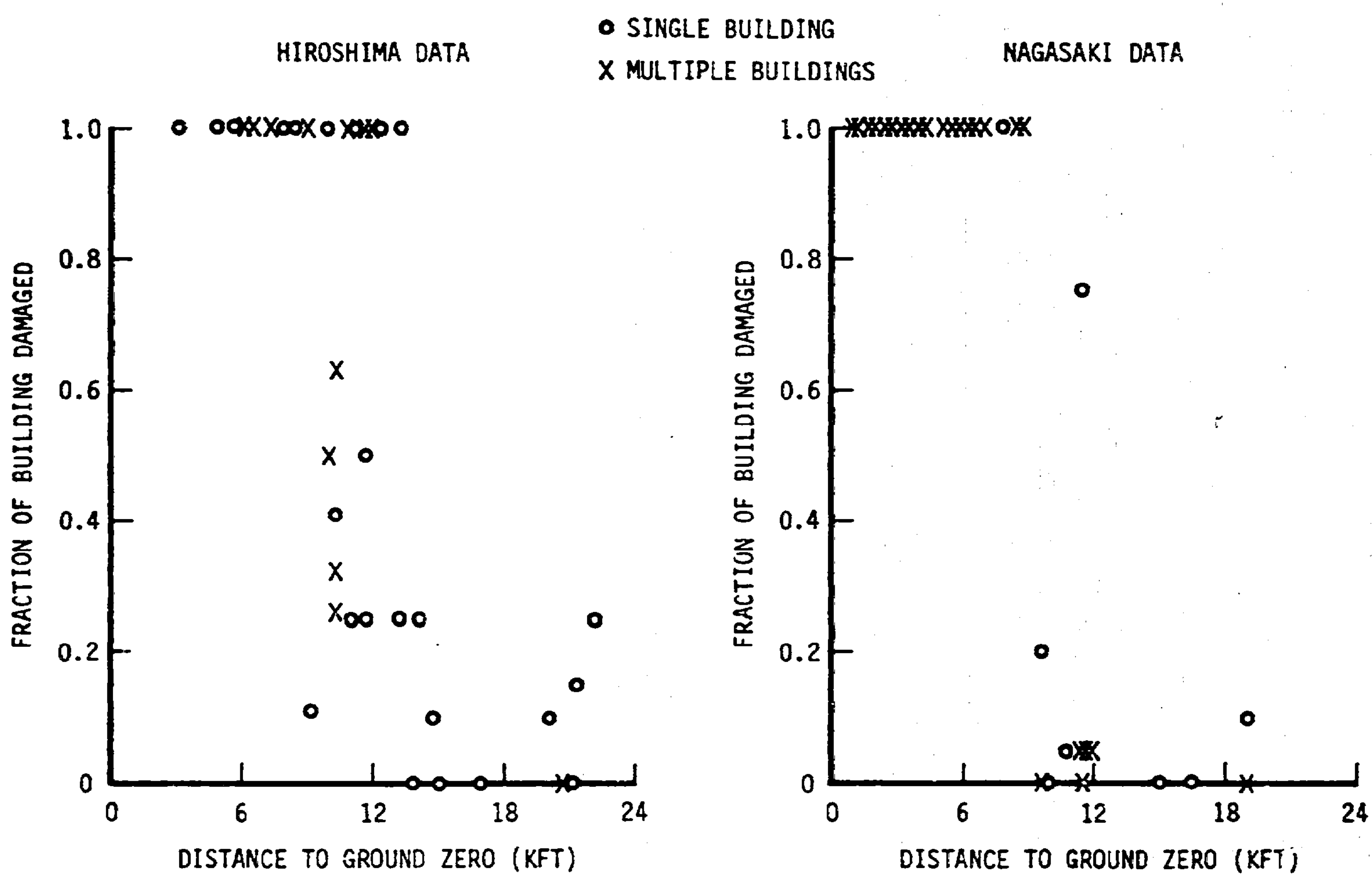
*This map is apparently the source of information for the designation of the areas damaged denoted on the map of Nagasaki contained in the Manhattan Engineering District Report, Reference 5.

FIGURE 15

DAMAGE-DISTANCE DATA FOR SUPERFICIAL DAMAGE CRITERIA

SINGLE-STORY WOOD FRAME BUILDINGS



The Single-Story Light Steel Frame Buildings in the data base have some widely differing wall construction details that merit enumeration before considering the results of the subclassification efforts in this structure class. Of the 90 buildings in the data base, two have such light lattice work steel columns that they would more properly be classified as Very Light Steel Frame Buildings; six have concrete panel walls; two have lattice steel columns that are filled with concrete, which apparently make these buildings much stronger than normal; and the remaining 78 buildings with known wall types have I-Beam or what will be called "normal" lattice steel columns with primarily either corrugated iron (fail slowly) and/or corrugated asbestos (fail quickly) wall and roof covering materials. The subclassification efforts for this structure class primarily involve the treatment of the 78 buildings with the I-Beam or normal lattice steel columns compared to the treatment of the 90 buildings as a whole.

Table 10 summarizes the results of the subclassification efforts for this structure class. As can be seen, the subclassification of the structures leads to some reduction in the value of the distance-damage sigma for all of the damage criteria involving Structural Damage. For the overall Structural Damage criteria, the estimated value of σ_d decreases by some 15 percent, while the estimated value of σ_d for the Structural Damage to Walls decreases by some 25 percent. The decrease in the value of σ_d of some 5 percent for the Structural Damage to Roofs criteria is, of course, more modest but apparently real.

Also shown, in parentheses, are the values of Q_{50} and σ_d that are derived after excluding the building at Nagasaki located some 11,400 feet from the ground zero identified as 52-12C6. This building has very unusual Structural Damage levels in that the nearest building of the same classification that has any Structural Damage is some 5000 feet closer to the ground zero. The Structural Damage levels for this building appear to be more in consonance with the Superficial Damage levels of the other Light Steel Frame Buildings at similar distances to the ground zero.

TABLE 10

EFFECT OF SUBCLASSIFICATION ON VALUE OF σ_d

Single-Story Light Steel Frame Buildings

- Specified Damage Fraction = 0.5
- Hiroshima Yield Assumed = 12 Kt

DAMAGE CRITERIA	STRUCTURE SUBCLASSIFICATION	Q_{50}(PSI)/σ_d
STRUCTURAL	None	0.47/0.390
	I-Beam or Normal Lattice Steel Columns	0.49/0.329
	(Less Bldg. 52-12C6)	(0.53/0.271)
STRUCTURAL TO WALLS	None	0.54/0.386
	I-Beam or Normal Lattice Steel Columns	0.54/0.286
	(Less Bldg. 52-12C6)	(0.53/0.272)
	I-Beam or Normal Lattice Steel Columns, Wall Cover Material Fails Slowly	0.63/0.358
STRUCTURAL TO ROOFS	None	0.62/0.345
	Roof Cover Material Fails Slowly	0.50/0.328
SUPERFICIAL	None	0.09/0.241
		1.88/0.229 *

*Using calculated peak overpressure rather than calculated peak dynamic pressure to determine value of σ_d.

Exclusion of this building has a marked effect in the value of the distance-damage sigma for the case of the Structural Damage criteria, reducing the value by some 20 percent. The effect with the Structural Damage to Walls criteria is less pronounced, amounting to about a five percent reduction. Both reductions, however, bring the estimated values of σ_d for these damage criteria much more in line with the value for the Superficial Damage criteria.

The attempt to further subclassify the buildings with I-Beam or normal lattice steel columns according to whether the wall cover material failed slowly (i.e., corrugated iron wall cover material) or quickly (i.e., corrugated asbestos) met with failure. Intuitively, one would expect the buildings with wall cover materials that fail quickly to be harder than the buildings with wall covers that fail slowly, since the wall cover material that fails slowly should contribute some impulsive loading to the structure during the time that it is failing. By this reasoning, the value of Q_{50} for the case of wall cover materials that fail slowly should be lower than the value of Q_{50} obtained when treating both types of wall covering materials together. The corresponding values of Q_{50} shown in this table have exactly the opposite relationship. Thus, the estimated value of σ_d for the case of cover materials that fail slowly should be viewed with extreme distrust.

Table 11 summarizes the results of the subclassification efforts for the Heavy Steel Frame Building structure classification. Because of the limited number (40) of these buildings in the data base, no subclassifications beyond damage criteria gave sensible results and are therefore not shown in the table.

The most striking feature of these results is the marked difference between the values of σ_d for the Structural Damage criteria and the Structural Damage to Walls or Structural Damage to Roofs criteria. The differences in σ_d shown in the table, however, are probably not real, since the data set for the Heavy Steel Frame Buildings is relatively poor with a gap between about 5500 feet and 11,500 feet from the ground zero where there are no data points. This has the impact of producing very large uncertainties in the confidence regions containing the true

TABLE 11

EFFECT OF SUBCLASSIFICATION ON THE VALUE OF σ_d

Single-Story Heavy Steel Frame Buildings

- Specified Damage Fraction = 0.5
- Hiroshima Yield Assumed = 12 Kt

DAMAGE CRITERIA	STRUCTURE SUBCLASSIFICATION	Q_{50}(PSI)/σ_d
STRUCTURAL	None	0.45/0.293
STRUCTURAL TO WALLS	None	0.65/0.400
STRUCTURAL TO ROOFS	None	0.42/0.409
SUPERFICIAL	None	0.15/0.363 2.49/0.381*
	None (Single and Multi-story Buildings)	0.18/0.335 2.88/0.344*

*Derived using calculated peak overpressure rather than calculated peak dynamic pressure to determine value of σ_d.

values of the mean and the standard deviation of the Cumulative Log Normal Damage Law. For example, at the 0.5 confidence level, the values of the damage-distance sigma can only be defined to within a factor of about 1.6 above or below the values indicated in the table.

D. DAMAGE TO GLASS

Figures 16 and 17 show the fraction of the glass in the building broken versus distance to the ground zero data for Hiroshima and Nagasaki, respectively. While the number of data points at Hiroshima are quite numerous, only eight out of the 224 buildings have less than complete glass breakage and no building has zero glass breakage. The situation with the Nagasaki data is somewhat better with 41 out of the 480 buildings having less than total glass breakage, including six buildings with a breakage level of zero.

In general, the data somewhat resembles the Single-Story Wood Frame Building data in that glass breakage occurred at Hiroshima at much greater distances from the ground zero than at Nagasaki. There is a further similarity to the Wood Frame Buildings in that Reference 5 also mentions glass breakage at a 60,000-foot distance from the ground zero at Nagasaki. Again, this damage could not be verified with any other available information source.

Table 12 shows the best estimate values of the mean peak pressure required for a 0.5 probability of damage (P_{50}) and the distance-damage sigma (σ_d) derived from combining the Hiroshima and Nagasaki data through the mechanism of calculated peak overpressure. Three values of P_{50} are shown for each of the damage laws considered, representing the value of the Specified Damage Fraction as 0^+, 0.5, and 1^-, respectively.

The particular form of the damage law does not have any great effect on either the estimated values of P_{50} or the estimated values of the distance-damage sigma. The largest percentage difference in the value

FIGURE 16

DAMAGE VERSUS DISTANCE DATA

GLASS IN BUILDINGS AT HIROSHIMA

GLASS BREAKAGE

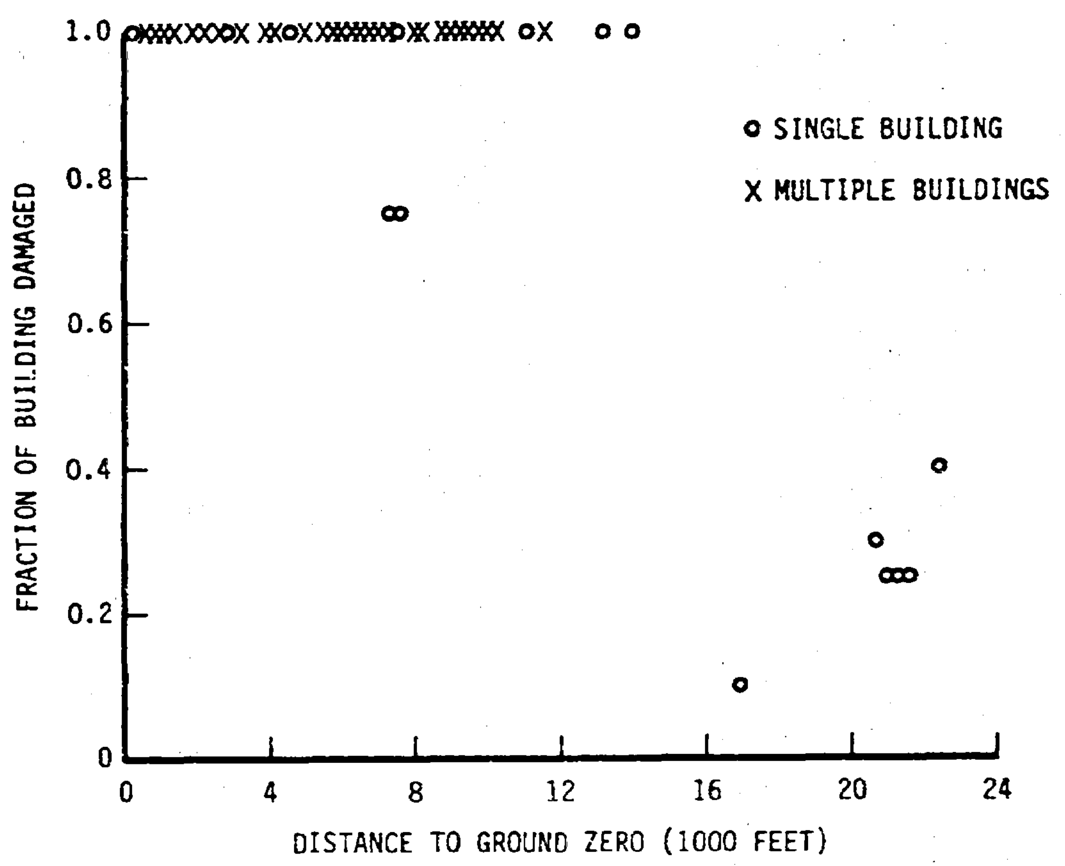


FIGURE 17

DAMAGE VERSUS DISTANCE DATA

GLASS IN BUILDINGS AT NAGASAKI

GLASS BREAKAGE

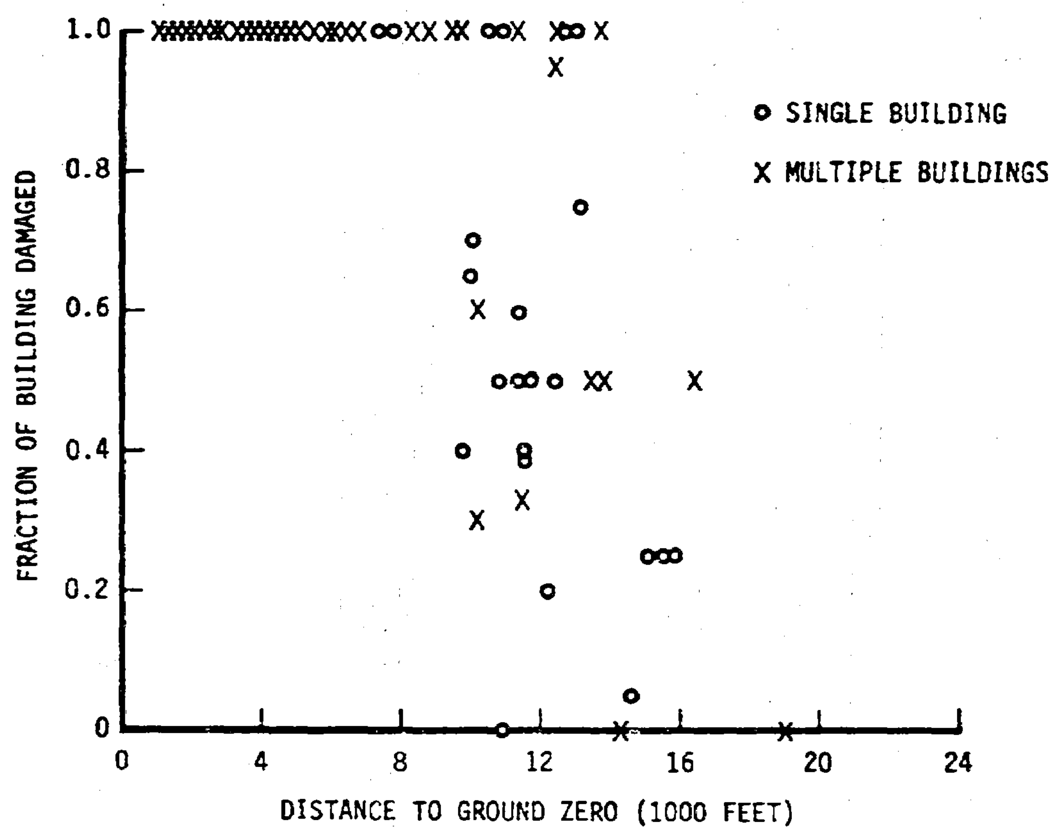


TABLE 12

EFFECT OF ASSUMED DAMAGE LAW ON VALUES OF P_{50} and σ_d

- Glass Breakage
- Hiroshima Yield Assumed = 12 Kt

DAMAGE LAW	σ_d	P_{50} (PSI)		
		SDF=0^+	SDF=0.5	SDF=1^-
CUMULATIVE LOG NORMAL	0.270	0.59	0.94	1.26
CUMULATIVE LOG UNIFORM	0.292	0.56	0.92	1.21
CUMULATIVE LOG TRIANGULAR	0.282	0.63	0.90	1.23

of P_{50} estimated from the different damage laws occurs with the Specified Damage Fraction (SDF) equal to 0^+. This should be expected since only six out of the 704 data points are denoted as undamaged for this value of the SDF.

Figure 18 compares the three probability of damage versus distance to the ground zero relationships derived for glass breakage at Nagasaki. The relationships are derived using the values of P_{50} and σ_d in Table 12 appropriate to the Specified Damage Fraction of 0.5.

The agreement between the Cumulative Log Normal and the Cumulative Log Triangular curves is not as good as was exhibited for the case of Structural Damage to Single-Story Masonry Load-Bearing-Wall Buildings (Figure 13). The results of applying "Goodness of Fit" tests, however, are similarly inconclusive in that any of the three damage laws can be accepted or rejected with about the same degree of confidence.

E. SENSITIVITY OF RESULTS TO YIELD ASSUMED FOR THE HIROSHIMA WEAPON

All of the values of the distance-damage sigma that have been presented up to this point have been based on assumed yields of 12 Kt for the Hiroshima weapon and 22 Kt for the Nagasaki weapon. This choice of 12 Kt for the Hiroshima weapon was based on providing the best overall match in the values of P_{50} for given structural classes and damage criteria when Hiroshima-only and Nagasaki-only data were considered.

Table 13 illustrates the effect of the assumed value of the Hiroshima yield on the values of the distance-damage sigma for the major structural classifications considered in the study when the value of the distance-damage sigma is estimated from both the Hiroshima and Nagasaki data combined through the mechanism of calculated peak pressure. The particular values shown are for the Structural Damage criteria.

In general, the assumed value of the yield of the Hiroshima weapon has a relatively small effect on the estimated values of the distance-damage sigma causing at most a 20 to 25 percent change in the estimated

FIGURE 18

COMPARISON OF PROBABILITY OF DAMAGE RELATIONSHIPS

GLASS BREAKAGE AT NAGASAKI

- SPECIFIED DAMAGE FRACTION = 0.5
- DERIVED FROM PRESSURE RESULTS (HIROSHIMA YIELD = 12 KT)

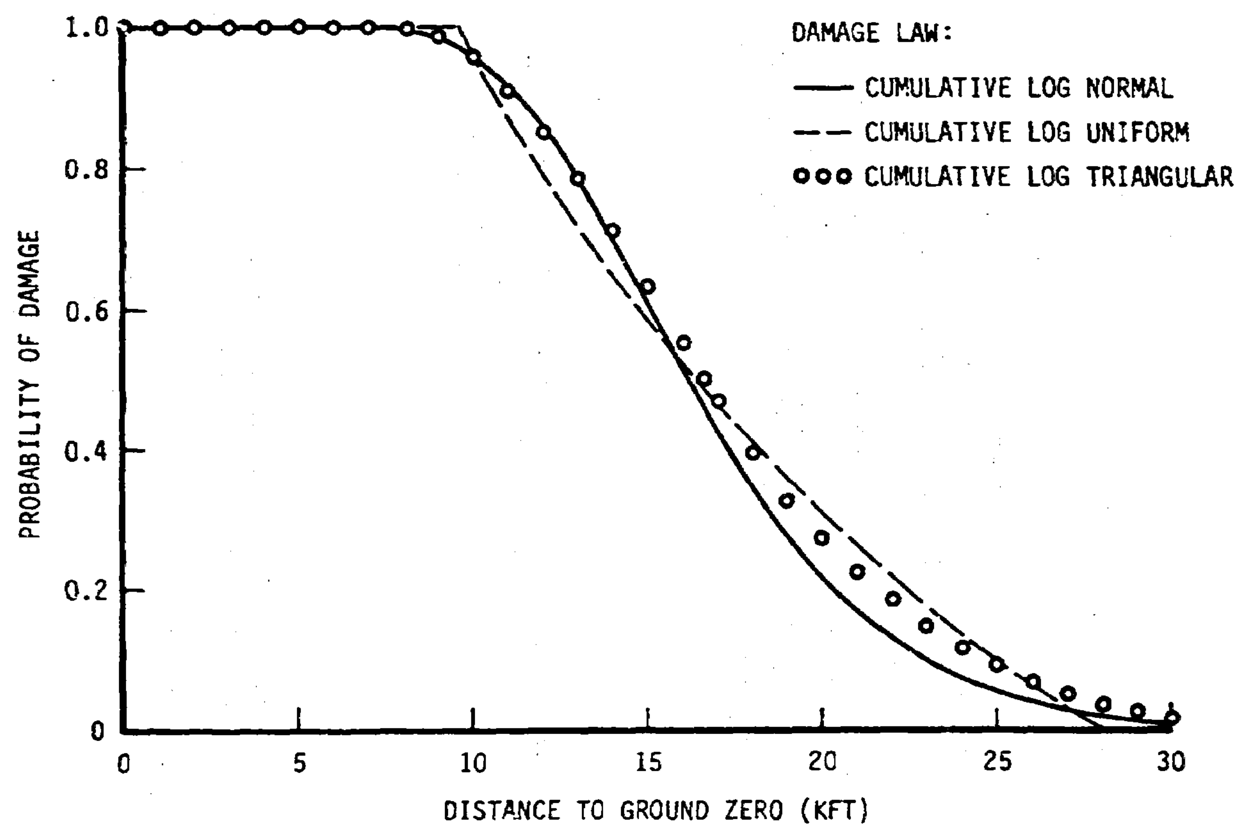


TABLE 13

EFFECT OF ASSUMED HIROSHIMA YIELD ON ESTIMATED VALUE OF σ_d

- Structural Damage Criteria
- Cumulative Log Normal Damage Law

STRUCTURE CLASSIFICATION	DISTANCE-DAMAGE SIGMA (σ_d) Assumed Hiroshima Yield: = 12 Kt	= 17 Kt	= 22 Kt
SINGLE-STORY MASONRY LOAD-BEARING-WALL	0.233	0.250	0.281
MULTISTORY MASONRY LOAD-BEARING-WALL	0.104	0.104	0.105
SINGLE-STORY WOOD FRAME	0.345	0.300	0.276
MULTISTORY WOOD FRAME	0.093	0.101	0.121
SINGLE-STORY LIGHT STEEL FRAME	0.390	0.392	0.398
SINGLE-STORY HEAVY STEEL FRAME	0.293	0.293	0.293

value of σ_d as the assumed yield goes from 12 Kt to 22 Kt. While not shown, the estimated values of the mean peak pressure required for a 0.5 probability of damage (P_{50} or Q_{50}) also increase in a systematic fashion with increasing assumed yield for the Hiroshima weapon.

With the exception of the Single-Story Wood Frame Buildings, the general trend is for the estimated value of σ_d to increase with increasing assumed yields for the Hiroshima weapon. The estimated values of σ_d for the Single-Story Wood Frame Buildings show exactly the opposite trend. This is due to the peculiarities in the Nagasaki data for this structure class, which were previously discussed in Section V.C. of this report.

Overall, these results indicate that the estimated values of the distance-damage sigma that are generated using the assumed yield of 12 Kt for the Hiroshima weapon are fairly good estimates that would not significantly change if a more precise estimate of the Hiroshima weapon's yield were obtained.

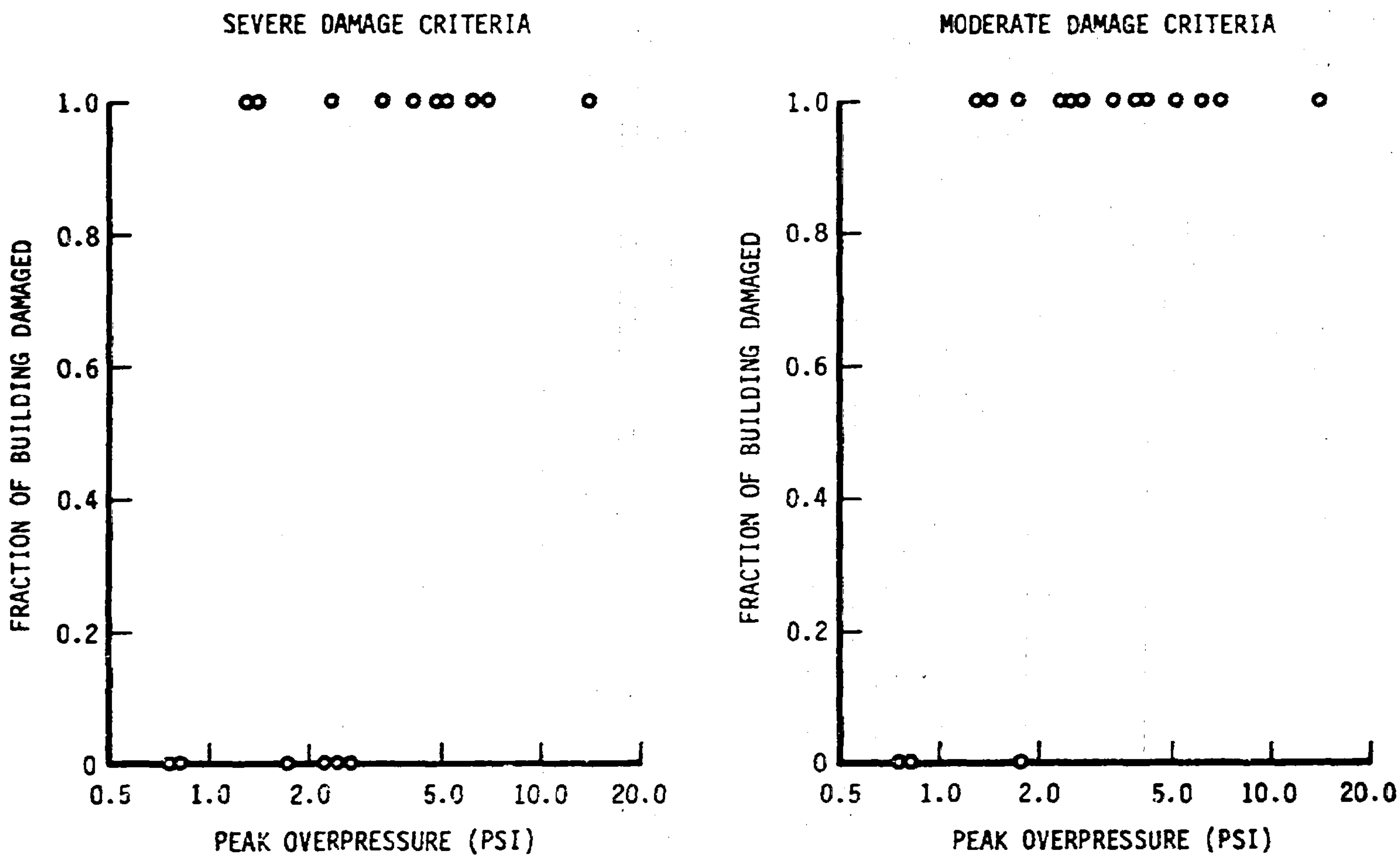
F. TEST SITE STRUCTURAL DAMAGE DATA

Single-Story and Multistory Wood Frame Buildings represent the only structure class where there are sufficient test site data to use statistical techniques to estimate the key parameters of the probability of damage versus peak pressure relationships. The available data set consists of some 17 buildings. The Structural Damage ascribed to these buildings is carried according to three criteria: Severe Structural Damage, Moderate Structural Damage, and Light Damage. All of the buildings suffered at least Light Damage.

Figure 19 shows the fraction of the building damaged versus peak overpressure data for the Severe and Moderate Damage criteria. The fraction damage levels are always unity or zero for these buildings, since the damage descriptions were all expressed in a pass-fail manner, i.e., the building either suffered, for example, Severe Structural Damage or it did not.

FIGURE 19

TEST SITE DATA FOR WOOD FRAME BUILDINGS



With two exceptions, the peak overpressure values shown are <u>measured</u> peak overpressure values rather than calculated values. This means that the uncertainties in weapons effects (assumed equivalent to a standard deviation of 0.10) must be combined with the standard deviation of the Cumulative Log Normal probability of damage versus peak pressure relationship before the estimated values of the distance-damage sigma can be calculated.

The Maximum Likelihood Estimates of the value of the standard deviation (β_P) of the Cumulative Log Normal Damage Law vary quite widely between the two damage criteria, being nearly twice as big for the Severe Damage as for the Moderate Damage criteria. Since Moderate Damage is an at-least criteria, this cannot be true, and a single value of β_P is required. Therefore, the average of the two values of β_P is used in determining the value of the distance-damage sigma and the mean peak pressures required for a 0.5 probability of damage (P_{50}).

Table 14 compares the values of P_{50} and σ_d estimated from the Test Site data with the values derived from the Japanese data on Single-Story and Multistory Wood Frame Buildings with Normal Walls and Roof Cover Materials that Fail Slowly. Two sets of values are shown for the Test Site data: the first for the data as shown in Figure 19; the second with the data points at 1.5 and 1.7 psi removed. (The rationale for removing these points is that they were obtained at a test that involved a multi-megaton device and appear to be out of line compared to the other data points, which were obtained in tests involving yields in the range of tens of kilotons.)

At first sight, the agreement between the estimated values of the distance-damage sigma for the cases of the Test Site data as a whole and the Japanese data is quite good, with the values differing by roughly seven percent. Similarly, the agreement between the values of P_{50} for the Severe Damage criteria with the Test Site data and the Structural Damage criteria (Specified Damage Fraction (SDF) = 1^-) with the Japanese data is also quite good, with the values differing by only a few percent.

TABLE 14

COMPARISON OF ESTIMATED VALUES OF P_{50} AND σ_d

Single-Story and Multistory Wood Frame Buildings

DATA SOURCE	NO. OF BUILDINGS	σ_d	DAMAGE CRITERIA	P_{50} (PSI)
TEST SITE DATA	17	0.259	Severe	2.16
			Moderate	1.38
MODIFIED TEST SITE DATA (See Text)	15	0.119	Severe	2.67
			Moderate	1.71
JAPANESE DATA	286	0.294	Structural (SDF=1^-)	2.01
			Structural (SDF=0.5)	1.95
			Structural (SDF=0^+)	1.59

The value of P_{50} for the Moderate Damage criteria and the Test Site data is considerably lower than even the SDF=0^+ value of P_{50} for the Japanese data. This is quite surprising, since according to their definitions the Moderate Damage criteria must correspond to the Structural Damage criteria with some SDF value greater than 0+ and less than 1^-.

Although the mean vulnerability level of Wood Frame Buildings is not normally denoted as being sensitive to yield, the two data points that were produced by the blast effects from the multimegaton device were deleted from the Modified Test Site data set. This produces a "best" estimate of the distance-damage sigma that is about a factor of two lower than the value estimated from the Japanese data. The best estimate values of P_{50} for the Modified Test Site data set are, however, more in consonance with the values estimated from the Japanese data. (The Japanese Wood Frame Buildings were generally denoted as having heavier roof construction and somewhat weaker wall construction than produced by standard United States construction practices circa 1945.)

Comparing the confidence regions for the values of P_{50} and β_P for the case of Moderate Damage and the Modified Test Site data with the confidence regions for the Structural Damage and the Japanese data reveals the relative uncertainties in the values of P_{50} and σ_d shown in Table 14. At the 0.5 confidence level, the "best" estimate value of σ_d for the Moderate Damage criteria is uncertain by a factor of about 2.3, while the "best" estimate of σ_d for the Structural Damage criteria is uncertain by a factor of about 1.2. At the 0.9 confidence level the corresponding uncertainty factors are about 5 and 1.5, respectively.

The uncertainties in the values of P_{50} are about a factor of 1.2 at the 0.5 confidence level and 1.4 at the 0.9 confidence level for both cases. There is, however, a fairly strong correlation effect present in the uncertainty regions for the Test Site data. This correlation effect produces the result that if the true value of σ_d is greater than the "best" estimate value shown for the Modified Test Site data set, the true values of P_{50} are most likely lower than the values shown in the table. No such effect is apparent in the confidence regions for the Japanese data.

Overall, this comparison of the Test Site data and the Japanese data for the Wood Frame Buildings gives ambiguous results in terms of the values of P_{50} and σ_d. The results suggest that the value of σ_d may be smaller for the Test Site buildings than for the Japanese buildings, but the uncertainties in the values of P_{50} and σ_d for the Test Site data are so large that a positive statement on the relative values of these parameters cannot be made with any degree of confidence.

G. CONFIDENCE LIMITS ON THE VALUE OF THE DISTANCE-DAMAGE SIGMA

The discussion up to this point has dealt mainly with the estimated values of the distance-damage sigma that are derived from the Maximum Likelihood Estimates of the key parameters of the probability of damage relationship. These estimates of the value of σ_d have ranged from about 0.1 to 0.4, depending on the structure classification, damage criteria, and damage law being considered. The purpose of this section is to examine the confidence limits on the true values of the distance-damage sigma that exist for several of the cases that have been examined in order to see what insight this will provide on resolving some of the ambiguities that have arisen in the discussion to date.

Figure 20 compares the confidence regions for P_{50} and σ_d that are derived using each of the three damage laws for the case of Structural Damage to the Single-Story Masonry Load-Bearing-Wall Buildings. The particular cases shown utilized the Unspecified Damage Fraction definition for the probability of damage. The MLE values of the distance-damage sigma derived from the three damage laws are: Cumulative Log Normal Damage Law, $\sigma_d = 0.233$; Cumulative Log Uniform Damage Law, $\sigma_d = 0.263$; and Cumulative Log Triangular Damage Law, $\sigma_d = 0.248$.

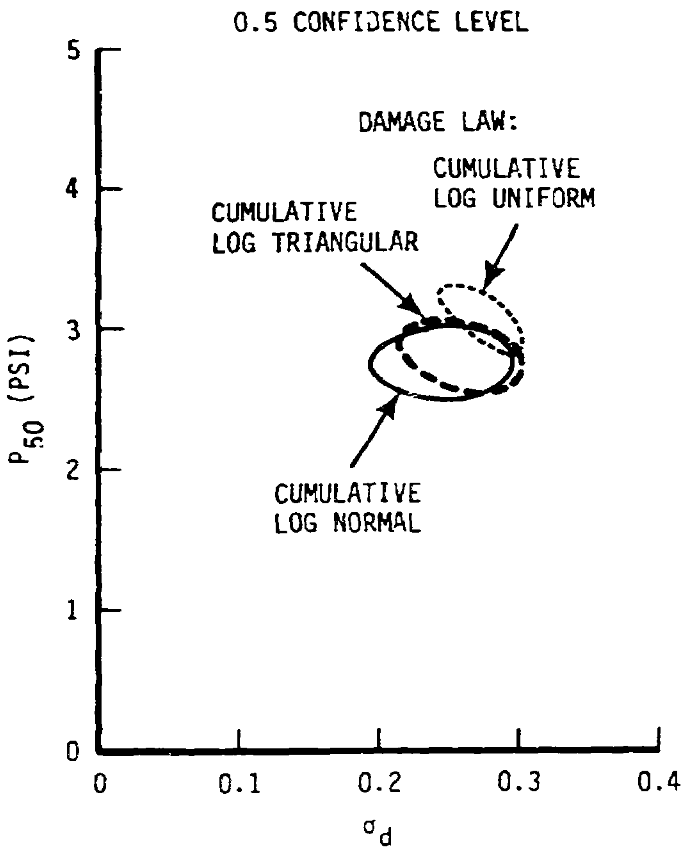
At both of the confidence levels shown in the figure, there is fairly good agreement among the three damage laws as to the upper bound on the value of σ_d, the 0.5 confidence level value being about 0.30 and the 0.9 confidence level value being about 0.37. The lower bound values, however, are somewhat different. At the 0.5 confidence level, the lower bound values of σ_d range from about 0.20 to 0.24 depending on

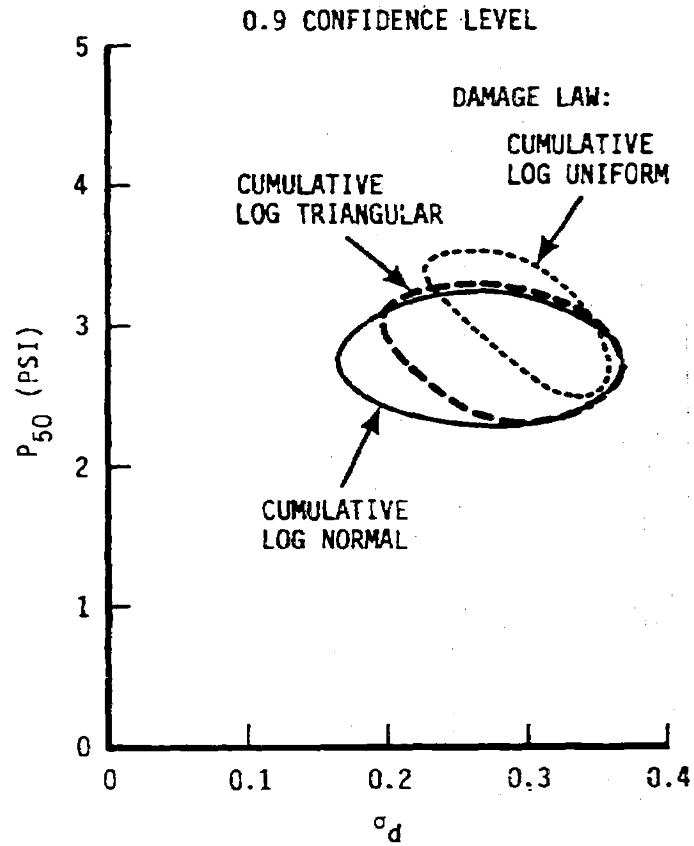
FIGURE 20

EFFECT OF DAMAGE LAW ON CONFIDENCE REGIONS

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

- STRUCTURAL DAMAGE CRITERIA (UDF VALUES)
- HIROSHIMA YIELD ASSUMED = 12 KT





which damage law is being considered, while at the 0.9 confidence level the lower bounds on σ_d range from about 0.17 to 0.23.

Part of the reason for these differences is understood and is data-set peculiar. For the Log Uniform and the Log Triangular Damage Laws, a bound exists on the lower left-hand side of the 0.9 confidence region that is defined by the highest calculated peak pressure at which a building in the data set has less than unity damage. This accounts for part of the difference between the Cumulative Log Normal and the Cumulative Log Triangular Damage Law regions at the 0.9 confidence level.

The extreme difference in shape of the confidence regions for the Cumulative Log Uniform Damage Law is not understood at all. The canted shape indicates that if the true value of σ_d is greater than the MLE estimate, then the true value of P_{50} is most likely less than the MLE estimate and vice versa. This sort of behavior is not a consequence of the shapes of the confidence regions for the other two damage laws. (The canted confidence regions for the Cumulative Log Triangular Damage Law should not be thought of as a reason for doubting the validity of this form of probability of damage relationship. Canted confidence regions occur in certain cases with the Cumulative Log Normal Damage Law.) Since the Cumulative Log Normal and the Cumulative Log Triangular Damage Laws generally give slightly better fits to the data than does the Cumulative Log Uniform Damage Law, only the former two damage laws will be used in the discussion that follows.

The principal difficulties with the Cumulative Log Normal Damage Law that have been mentioned up to this point are the differences in the point estimates of the values of the distance-damage sigma (σ_d) for the Structural and Superficial Damage criteria and the differences in the value of σ_d from one structure class to another. Differences in the value of σ_d for the Structural and Superficial Damage criteria have been particularly troublesome, since they lead to obvious absurdities.

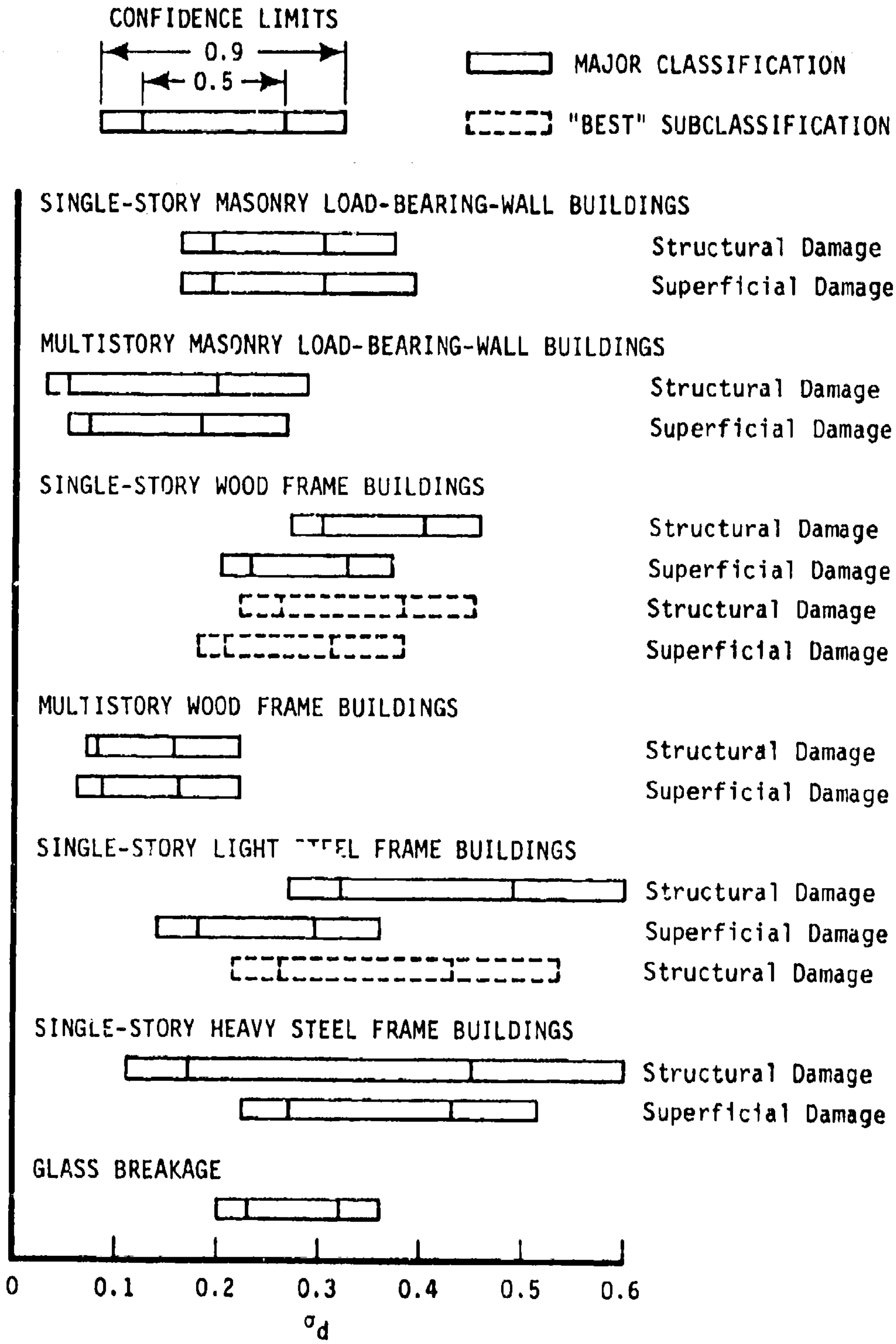
Figure 21 compares the 0.5 and 0.9 confidence limits on the values of the distance-damage sigma for the Structural and Superficial Damage criteria that are derived from the data sets for the various major

FIGURE 21

COMPARISON OF CONFIDENCE LIMITS ON VALUE OF σ_d

CUMULATIVE LOG NORMAL DAMAGE LAW

• HIROSHIMA YIELD ASSUMED = 12 KT



structural classifications considered in the analysis using the Cumulative Log Normal Damage Law. The particular values shown represent the maximum uncertainty in the value of σ_d for the given confidence level.

The agreement between the uncertainty regions for the two damage criteria is quite good for the Single-Story and Multistory Masonry Load-Bearing-Wall and Multistory Wood Frame Building cases. This should probably be expected, since the MLE values of the distance-damage sigma for the two damage criteria are nearly identical for these cases (see Table 5). The magnitude of the uncertainties in the value of σ_d for these cases also suggests that the uncertainties in the probability of damage versus distance relationship should be slightly larger for the case of the Multistory Masonry Load-Bearing-Wall Buildings and slightly smaller for the case of the Multistory Wood Frame Buildings than those shown in Figure 12 for the case of the Single-Story Masonry Load-Bearing-Wall Buildings.

The agreement between the confidence limits for σ_d is less satisfactory for the remaining three major structure classifications. For the Single-Story Wood Frame and Light Steel Frame Buildings, the confidence limits for the Superficial Damage criteria are somewhat lower than those for the Structural Damage criteria, while for the Heavy Steel Frame Buildings the confidence limits for Structural Damage are about 1.5 times as large as those for the Superficial Damage criteria. Since the value of σ_d must, for any particular structure class, be identical for the Structural and Superficial Damage criteria, this suggests that the most likely "true" value of σ_d for these cases is in the region of overlap of the confidence regions.

Also shown in the figure are the confidence limits for the two cases of structure subclassifications that were seen in Section V.C. to give apparently real reductions in the value of σ_d over the value found for the structure class as a whole, i.e., Single-Story Wood Frame Buildings with Normal Walls, Wood Roof Trusses, and Roof Cover Materials that Fail Slowly; and Single-Story Light Steel Frame Buildings with I-Beam or Normal Lattice Steel Columns. Comparison of these limits with the corresponding values for the major structural classification shows that the 0.5 confidence

limits are moved to the left (i.e., they encompass lower values of σ_d), while the 0.9 confidence limits span a somewhat larger span of values for σ_d. For the Single-Story Wood Frame Buildings, the agreement between the confidence limits for the Structural and Superficial Damage criteria is also improved somewhat.

Figure 22 shows similar data as that shown in Figure 21, except that the Cumulative Log Triangular Damage Law rather than the Cumulative Log Normal Damage Law is used to derive the values of the distance-damage sigma. The general trends shown in the figure are similar to those discussed with the case of the Cumulative Log Normal Damage Law. The major difference in the results is that the uncertainty regions for the value of the distance-damage sigma derived using the Cumulative Log Triangular Damage Law are generally somewhat smaller than the corresponding uncertainty regions derived using the Cumulative Log Normal Damage Law.

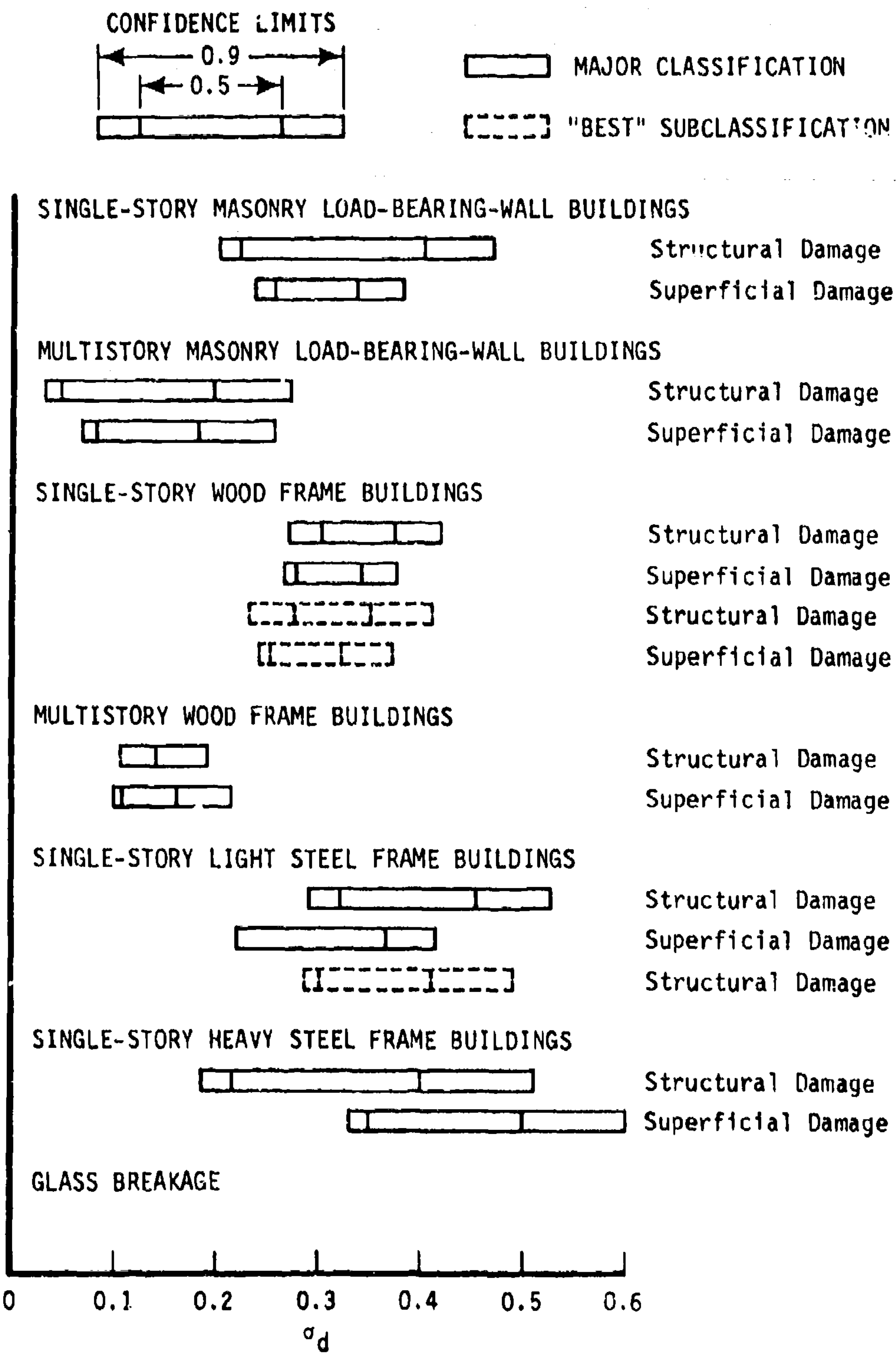
Overall, these confidence limits on the values of the distance-damage sigma suggest that the value of σ_d is almost certainly less for the Multistory Buildings, being most likely in the region of $\sigma_d = 0.10$ to $\sigma_d = 0.15$. (From Tables 5 and 7, the "best" estimate values of σ_d are, for both structure types, about 0.11). For the Single-Story Buildings (and Glass Breakage), these confidence limits suggest the "true" value of σ_d is most likely in the region of $\sigma_d = 0.25$ to 0.35, with perhaps some difference in the value of σ_d from one structure class to another.

FIGURE 22

COMPARISON OF CONFIDENCE LIMITS ON VALUE OF σ_d

CUMULATIVE LOG TRIANGULAR DAMAGE LAW

• HIROSHIMA YIELD ASSUMED = 12 KT



VI. REFERENCES

1. "The Effects of the Atomic Bomb on Hiroshima, Japan," Physical Damage Division, United States Strategic Bombing Survey, Volumes I, II, and III, May 1947.

2. "The Effects of the Atomic Bomb on Nagasaki, Japan," Physical Damage Division, United States Strategic Bombing Survey, Volumes I, II, and III, June 1947.

3. "Incidents in Hiroshima," Part III, Report of the Bureau of Yards and Docks Mission to Japan 1945, undated.

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7. "Introduction to Mathematical Statistics," Third Edition, Paul G. Hael, John Wiley and Sons, Inc., August 1966.

8. "Mathematical Background and Programming Aids for the Physical Vulnerability System for Nuclear Weapons," DI-550-27-74, Defense Intelligence Agency, 1 November 1974.

APPENDIX A

BUILDINGS IN STRUCTURE OR GLASS DAMAGE DATA FILES

The buildings at Hiroshima and Nagasaki are divided into seven major types of structures: Masonry Load-Bearing-Wall, Wood Frame, Light Steel Frame, Heavy Steel Frame, Heavy Steel Frame with heavy cranes (>25 tons), Reinforced Concrete Frame, and Composite Buildings. All types are used for Structural, Superficial, and Glass Damage, except the last two types which are used only for Glass Damage and occasionally for Roof Damage.

Each entry in the data file represents a building (or group of several identical buildings) and contains a building identifier, indicates the city, whether it is single-story or multistory, and the distance from the ground zero. Each type is subdivided according to wall and roof types based on the structural members and covering material. The damage is reported in four percentages: Structural Damage to Walls (if load-bearing) or framing, Structural Damage to Roofs, Superficial Damage, and Glass Breakage. The Structural Damage percentage is the fraction of the building damaged structurally. The Superficial Damage indicates the fraction of the total surface area of the roof and wall covering material damaged. In the case of Masonry Load-Bearing-Wall Buildings, no Superficial Damage is possible to the walls without causing Structural Damage. The percentage in this instance is the fraction of the roof covering damaged.

The study also examined Structural Damage criteria as well as the above four. This criteria is defined as the maximum of Structural Damage to Walls and Structural Damage to Roofs. In some cases, one or more of the damage percentages is not available due to incomplete data. The data file also indicates the source document for each building and any additional comments deemed necessary for explanation. The exhibits at the end of this appendix present all the data files used in the study, together with a list of other buildings not included and the reason for exclusion.

A. WALL TYPE

It was desirable in the analysis to subdivide the buildings by the type of wall or load-bearing member. When the type of wall was unknown, this was indicated by Type 9.

For Masonry Load-Bearing-Wall Buildings, the thickness of the load-bearing-walls was an important characteristic. The following table explains the classifications.

MASONRY LOAD-BEARING-WALL TYPES

Wall Thickness (Inches)

Wall Type	Minimum Thickness	Maximum Thickness
5	7	9
6	12	14
7	17	19
8	23	27

Wood Frame Buildings are primarily of Wall Type 1, but a few buildings are different enough to warrant two separate wall types. Type 2 contains those structures that have wall coverings of quick-failing material, such as corrugated asbestos or in some instances open walls with no covering material at all. Type 5 includes those Wood Frame Buildings reinforced with heavy steel crane columns.

The three Steel Frame classifications all have the same divisions of wall types. The two major types are: 1) normal columns with slow-failing wall covering material (i.e., corrugated iron) and 2) normal columns with quick-failing wall covering material. Normal columns are I-beams, lattice steel columns or similar. The four other types are special cases: 3) buildings with very light columns, 4) buildings having concrete panel walls, 5) buildings with reinforced concrete walls around the steel columns, and 6) buildings with lattice steel columns filled with concrete for added strength.

The reinforced concrete frame and composite structure buildings are not subdivided by wall type, since wall damage for those types are not examined in this study. Note also that Multistory Heavy Steel Frame Buildings are not divided into heavy and light crane columns. This information was only available for the single-story buildings.

B. ROOF TYPE

The roofs of the buildings are basically of five types regardless of the kind of building frame, so that the roof type classification is the same for all buildings. The classification depends upon the structural member or trusses and the roof covering material. The following table summarizes roof types.

ROOF TYPES

Type	Structural Members	Covering Material
1	Rein. Concrete	Slow-Failing
2	Steel	Slow-Failing
3	Steel	Quick-Failing
4	Wood	Slow-Failing
5	Wood	Quick-Failing
9	Unknown	Unknown

Some of the reinforced concrete frame and composite structures contain roofs of Types 2-5. In these instances, the roof type and Structural Damage to Roofs were included in the data file and the analysis. Damage to reinforced concrete roofs was, in general, not of interest to the study.

C. KEY TO DATA FILES

1. Building Identifier

Each entry in the data file contains a building number and group identifier (if applicable) used in the source documents. In some cases, the buildings are subdivided one or two times. For example, Group 52,

Building Number 5, Subdivision B1 and B2. If more than one building is included in a single entry, the numbers are separated by commas or a dash to indicate a sequence. (For example, 6A1-4 indicates four buildings from 6A1 to 6A4.)

2. Type

Wall and Roof type explained above.

3. Distance

Distance from the building to the ground zero in feet.

4. Damage

Structural Damage to Walls, Roofs; Superficial Damage to Wall and Roof Covers; and Glass Damage as explained previously. Percent of building damaged.

5. Source

The primary source document for each building entry is indicated according to the following abbreviations:

SBS I, II, or III:	Strategic Bombing Survey Report, Volume I, II, or III for Hiroshima or Nagasaki (as indicated in the title heading).
BYD:	Report of the Bureau of Yards and Docks Mission to Japan 1945. Incidents in Hiroshima.
SBS WORKING PAPERS: (or Notes)	From the working papers and notes of the Strategic Bombing Survey Teams at the National Archives.

6. Comments

Other explanatory information is included in this column.

EXHIBIT A-1

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
	3	7	2	900	1.00	1.00	1.00	1.00	SBS II	
	5	7	4	100	1.00	1.00	1.00	1.00	SBS II	
	15	7	3	2200	1.00	1.00	1.00	1.00	SBS II	Contains crane rails
	35B	7	2	6400	0	0	.50	1.00	SBS II	Reinforced concrete 1st floor
	37	5	4	4200	1.00	1.00	1.00	1.00	SBS II	
	53	6	4	3200	1.00	1.00	1.00	1.00	SBS II	Damage too severe for detail analysis
	54	5	4	3100	1.00	1.00	1.00	1.00	SBS II	Damage too severe for detail analysis
68	A,B,C	7	2	2600	1.00	1.00	1.00	1.00	SBS II	Brick walls & steel frame
	69	7	2	2200	1.00	1.00	1.00	1.00	SBS II	
	72	6	4	6200	1.00	1.00	1.00	1.00	SBS II	
	82	6	4	3900	1.00	1.00	1.00	1.00	SBS II	Crane rail in part of building
	84	6	2	3300	1.00	1.00	1.00	1.00	SBS II	
	103	7	4	5500	.06	0	1.00	1.00	SBS II	
	106	5	2	3900	1.00	1.00	1.00	1.00	SBS II	
	111	5	5	6000	1.00	1.00	1.00	1.00	SBS II	
113	E	7	4	7300	0	0	0	-	SBS II	
113	F	7	4	7200	0	.43	.43	1.00	SBS II	
	117	7	2	7900	0	0	0	1.00	SBS II	Massive bldg with heavy buttresses
123	A	6	4	7000	1.00	1.00	1.00	1.00	SBS II	
123	B	6	4	7300	0	.20	.30	1.00	SBS II	
127	C	5	4	8300	0	.83	1.00	1.00	SBS II	
127	D	5	4	8600	0	0	0	1.00	SBS II	

EXHIBIT A-1

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA (Cont.)

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
127	E	5	4	8600	0	.71	.71	1.00	SBS II	
127	F,G,H	5	5	8500	0	0	.60	1.00	SBS II	
130	C	6	4	8200	0	1.00	1.00	1.00	BYD	
130	D	9	4	8200	0	1.00	1.00	1.00	BYD	
130	H	6	2	8300	1.00	1.00	1.00	1.00	BYD	
130	I	9	9	8200	1.00	1.00	1.00	1.00	BYD	
131	A	8	3	7700	0	0	1.00	1.00	SBS II	
131	B	8	3	7700	0	0	1.00	1.00	SBS II	
	220	9	2	6600	0	0	1.00	1.00	BYD	
WFP	1	6	1	9200	0	0	0	1.00	SBS III	
WFP	2	9	2	9200	0	0	0	1.00	SBS III	
WFP	3	8	2	9200	0	0	.07	1.00	SBS III	
WFP	4	9	2	9200	0	0	.33	1.00	SBS III	
WFP	5	6	1	9200	0	0	0	1.00	SBS III	
WFP	6	6	2	9200	0	0	.24	1.00	SBS III	
WFP	7	5	1	9200	0	0	0	1.00	SBS III	
WFP	9	9	2	9200	0	0	0	1.00	SBS III	
JSC-67	B-E	9	4	20800	0	0	0	--	SBS III & Notes	
JSC-67	I	9	4	20900	0	0	0	--	SBS III & Notes	
JSC-67	L	9	4	20800	0	0	0	--	SBS III & Notes	

EXHIBIT A-2

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
5	3	5	5	3600	1.00	1.00	1.00	1.00	SBS I	
5	75	9	1	3200	1.00	1.00	1.00	1.00	SBS I	Brick walls, concrete roof
15	1	8	5	1800	1.00	1.00	1.00	1.00	SBS II	Very heavy brick with buttresses
17	16	6	4	1400	1.00	1.00	1.00	1.00	SBS II	
20	28	6	4	2400	1.00	1.00	1.00	1.00	SBS II	
20	38B	6	4	1900	1.00	1.00	1.00	1.00	SBS II	
33	1	9	1	5400	1.00	1.00	1.00	1.00	SBS I	
33	2	6	4	5400	1.00	1.00	1.00	1.00	SBS I	
36	9	9	4	5400	1.00	1.00	1.00	1.00	SBS I	
36	11-14	9	4	5300	1.00	1.00	1.00	1.00	SBS I	
36	17	6	4	4800	1.00	1.00	1.00	1.00	SBS I	
36	18	6	2	4800	.40	0	1.00	1.00	SBS I	Rein. concrete blast blocks (7 ft)
36	19	6	4	4800	1.00	1.00	1.00	1.00	SBS I	
36	22	6	3	4900	.50	1.00	1.00	1.00	SBS I	
37	3	6	4	5500	.80	1.00	1.00	1.00	SBS II	Steel columns (6" x 6")
39	1	8	2	6700	1.00	1.00	1.00	1.00	SBS I	Very thick walls
40	1W	6	2	6300	1.00	1.00	1.00	1.00	SBS I	
40	3	6	2	6300	1.00	1.00	1.00	1.00	SBS I	
40	7	5	3	6400	.10	1.00	1.00	1.00	SBS I	
40	8	6	5	6400	.10	1.00	1.00	1.00	SBS I	
40	10	6	5	6500	1.00	1.00	1.00	1.00	SBS I	
49	A,B,C	6	4	8800	1.00	1.00	1.00	1.00	SBS I	

EXHIBIT A-2

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI (Cont.)

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
52	1A1	9	5	12,200	0	0	.05	.20	SBS I	
52	1B1-4	9	5	12,200	0	0	0	--	SBS I	
52	2D	9	5	12,000	0	0	0	--	SBS I	
52	4A	9	3	11,500	0	0	0	--	SBS I	
52	10B2	6	3	11,300	0	0	1.00	--	SBS I	
52	18C	9	4	10,200	0	0	0	--	SBS I	
58	4	9	4	20,000	0	0	0	--	SBS Work. Paper	
58	5	9	4	20,000	0	0	0	--	SBS Work. Paper	
58	6	9	5	20,000	0	0	0	--	SBS Work. Paper	
58	36	9	2	17,000	0	0	0	--	SBS Work. Paper	
70	1	9	4	8,800	0	1.00	1.00	1.00	SBS II	
81	3	5	4	10,900	0	0	0	0	SBS II	
93	1-7	9	2	18,700	0	0	.10	--	SBS I	Brick and concrete
SEGS	1	9	4	6,700	.25	1.00	1.00	--	SBS Work. Paper	
SEGS	2,3	9	2	6,700	0	1.00	1.00	--	SBS Work. Paper	

EXHIBIT A-3

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
	4	8	4	400	1.00	1.00	1.00	1.00	SBS II	
	7	8	1	500	1.00	1.00	1.00	1.00	SBS II	27" brick walls with rein. concrete spandrels and tie beams
	10	7	1	600	1.00	1.00	1.00	1.00	SBS II	
	13	8	4	1300	1.00	1.00	1.00	1.00	SBS II	
	14	6	4	1400	1.00	1.00	1.00	1.00	SBS II	
	17	7	4	900	1.00	1.00	1.00	1.00	SBS II	
	29	5	4	4200	1.00	1.00	1.00	1.00	SBS II	
	32C	9	4	4900	1.00	1.00	1.00	1.00	SBS II	
	34	6	5	5200	1.00	1.00	1.00	1.00	SBS II	
	35A	8	2	6400	0	0	.83	1.00	SBS II	
	36	6	4	6600	.27	.64	.85	1.00	SBS II	
	45	8	1	1800	1.00	1.00	1.00	1.00	SBS II	
	55	7	4	3100	1.00	1.00	1.00	1.00	SBS II	
66	A-D	7	4	4200	1.00	1.00	1.00	1.00	SBS II	
	92	7	4	1300	1.00	1.00	1.00	1.00	SBS II	
	110	7	4	5900	0	.50	1.00	1.00	SBS II	
127	B	5	4	8500	0	0	.50	1.00	SBS II	
130	E1	9	9	8500	0	0	0	1.00	BYD	
130	G	9	4	8600	0	0	.50	1.00	BYD	
201	1A	9	4	8700	0	0	0	1.00	BYD	3 buildings
201	1B	9	4	9000	0	0	0	1.00	BYD	
201	1C	9	4	9300	0	0	0	1.00	BYD	

EXHIBIT A-3

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA (Cont.)

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
201	1D	9	4	9500	0	0	0	1.00	BYD	
201	1E	9	4	9850	0	0	0	1.00	BYD	2 buildings
201	1F	9	4	10000	0	0	0	1.00	BYD	2 buildings
	219	9	5	8300	0	0	0	--	BYD	

EXHIBIT A-4

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
52	2A1	9	5	12,000	0	0	0	--	SBS I	
52	4B-E	9	3	11,500	0	0	0	.33	SBS I	
52	10B1	6	5	11,300	0	0	0	--	SBS I	
58	2	9	4	20,000	0	0	0	--	SBS Work. Paper	
84	1	6	4	13,100	0	0	0	.75	SBS II	
84	2	9	4	13,000	0	0	0	1.00	SBS II	
84	3	6	4	12,700	0	0	0	1.00	SBS II	

EXHIBIT A-5

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
	80	5	5	5900	0	.31	1.00	1.00	SBS II	Building contains crane rail
	88	1	4	9400	1.00	1.00	1.00	1.00	SBS II	
	89	1	4	9700	0	0	1.00	1.00	SBS II	
	90	2	4	9900	.72	.72	1.00	1.00	SBS II	
91	B1-9	1	4	15000	0	0	0	--	BYD	Very little data available
	97	2	5	6000	1.00	1.00	1.00	1.00	SBS II	
	99	1	5	6500	1.00	1.00	1.00	1.00	SBS II	
102	A	5	4	4900	.26	.30	1.00	1.00	SBS II	Building contains crane rail
112	C	1	5	6600	1.00	1.00	1.00	1.00	SBS II	
112	D	1	5	6600	1.00	1.00	1.00	1.00	SBS II	
113	B	1	4	7700	1.00	1.00	1.00	1.00	SBS II	
113	G	1	4	7100	1.00	1.00	1.00	1.00	SBS II	
116	D	1	5	9000	0	0	1.00	1.00	SBS II	
116	L	1	4	9200	1.00	.11	1.00	1.00	SBS II	
116	M	1	5	9100	.11	.11	.11	1.00	SBS II	
118	2	1	9	9000	1.00	1.00	1.00	1.00	BYD	
125	A,B,C	1	5	9000	1.00	1.00	1.00	1.00	SBS II	
201	2	1	4	9300	1.00	1.00	1.00	1.00	BYD	12 buildings
212	1-4	1	4	10300	.15	0	.32	1.00	BYD	
212	5	1	4	10300	0	0	.41	1.00	BYD	
212	6,7	1	4	10300	.15	0	.26	1.00	BYD	
212	8	1	4	10300	.63	.63	.63	1.00	BYD	

EXHIBIT A-5

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA (Cont.)

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
	213	1	5	10000	.50	.50	.50	1.00	BYD	
	214	1	9	10700	1.00	1.00	1.00	1.00	BYD	
222	2	1	9	8300	1.00	1.00	1.00	1.00	BYD	
PS	1	1	4	16900	0	0	0	.10	SBS III & Notes	
PS	2	1	4	13200	1.00	1.00	1.00	1.00	SBS III & Notes	
PS	3	1	4	14000	0	0	.25	1.00	SBS III & Notes	
PS	4	1	4	11100	0	0	.25	1.00	SBS III & Notes	
PS	5	1	4	13200	0	0	.25	--	SBS III & Notes	
PS	8	1	4	7300	0	0	1.00	1.00	SBS III & Notes	
PS	11	1	4	3100	1.00	1.00	1.00	1.00	SBS III & Notes	
PS	12	1	4	11600	0	0	.25	1.00	SBS III & Notes	
PS	12A	1	4	11600	0	0	.50	--	SBS III & Notes	
PS	13	1	4	14800	0	0	.10	--	SBS III & Notes	
JSC	24	1	4	20800	0	0	0	--	SBS III & Notes	
JSC	26	5	4	21300	0	0	.15	--	SBS III & Notes	
JSC	34-5	1	4	20100	0	0	.10	--	SBS III & Notes	
JSC	67A	1	4	20800	0	0	0	--	SBS III & Notes	
JSC	67G	1	4	21000	0	0	0	--	SBS III & Notes	
JSC	76E	5	4	22200	0	0	.25	--	SBS III & Notes	
WSPS	1	1	4	6600	1.00	1.00	1.00	--	SBS No[illegible]	
WSPS	2	1	4	5600	1.00	1.00	1.00	--	SBS Notes	
AP	2	1	4	13700	0	0	0	--	SBS Notes	

EXHIBIT A-5

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA (Cont.)

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
AP	3	1	5	11600	1.00	1.00	1.00	--	SBS Notes	
AP	4	1	5	11800	1.00	1.00	1.00	--	SBS Notes	
AP	5	1	4	10900	1.00	1.00	1.00	--	SBS Notes	
AP	6	1	4	11200	1.00	1.00	1.00	--	SBS Notes	
AP	7	1	4	11400	1.00	1.00	1.00	--	SBS Notes	
AP	8	1	4	11700	1.00	1.00	1.00	--	SBS Notes	
AP	9	1	4	11900	1.00	1.00	1.00	--	SBS Notes	

EXHIBIT A-6

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
1	2-4	1	4	5800	1.00	1.00	1.00	1.00	SBS II	
1	5A,6	1	4	5800	1.00	1.00	1.00	1.00	SBS II	
1	9	9	4	5800	1.00	1.00	1.00	1.00	SBS II	
2	1	1	9	5200	1.00	1.00	1.00	--	SBS Notes	
4	6	2	5	5000	1.00	1.00	1.00	1.00	SBS I	
4	9	1	5	5000	1.00	1.00	1.00	1.00	SBS I	
4	9A	1	4	5000	1.00	.50	1.00	1.00	SBS I	
4	9C	2	5	5000	1.00	1.00	1.00	1.00	SBS I	
4	9D	1	4	5000	1.00	1.00	1.00	1.00	SBS I	
4	14	1	5	4300	1.00	1.00	1.00	1.00	SBS I	
4	15-16	1	4	5500	1.00	1.00	1.00	1.00	SBS I	
4	17	1	4	5400	1.00	1.00	1.00	1.00	SBS I	
4	26,27	1	4	4100	1.00	1.00	1.00	1.00	SBS I	
4	29,30	1	4	3900	1.00	1.00	1.00	1.00	SBS I	
4	31	1	4	3800	1.00	1.00	1.00	1.00	SBS I	
4	33	1	4	4200	1.00	1.00	1.00	1.00	SBS I	
4	36A	1	9	3600	1.00	1.00	1.00	1.00	SBS I	
5	4	1	5	3600	1.00	1.00	1.00	1.00	SBS I	
5	5	1	5	3200	1.00	1.00	1.00	1.00	SBS I	
5	7N	9	4	3200	1.00	1.00	1.00	1.00	SBS I	
5	8	1	5	3200	1.00	1.00	1.00	1.00	SBS I	
5	9	2	5	3200	1.00	1.00	1.00	1.00	SBS I	

EXHIBIT A-6

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI (Cont.)

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
6	1	1	4	3500	1.00	1.00	1.00	1.00	SBS I	
6	2	1	4	3500	1.00	1.00	1.00	1.00	SBS I	
6	3	1	4	3600	1.00	1.00	1.00	1.00	SBS I	
9	1	1	4	2600	1.00	1.00	1.00	1.00	SBS II	
9	2,5	1	4	2600	1.00	1.00	1.00	1.00	SBS II	
10	1	1	4	3700	1.00	1.00	1.00	1.00	SBS II	
10	5-7	1	4	3700	1.00	1.00	1.00	1.00	SBS II	
13	1	1	4	1000	1.00	1.00	1.00	1.00	SBS II	8 buildings
13	3	1	4	1100	1.00	1.00	1.00	1.00	SBS II	
13	5	1	4	1000	1.00	1.00	1.00	1.00	SBS II	
13	7	1	4	1200	1.00	1.00	1.00	1.00	SBS II	
14	2-5	1	3	1900	1.00	1.00	1.00	1.00	SBS II	
15	2	1	4	1800	1.00	1.00	1.00	1.00	SBS II	
15	4	1	4	2200	1.00	1.00	1.00	1.00	SBS II	
17	1-5	1	4	2000	1.00	1.00	1.00	1.00	SBS II	
17	6-8	1	4	1900	1.00	1.00	1.00	1.00	SBS II	
17	9-11	1	4	1800	1.00	1.00	1.00	1.00	SBS II	
17	13,15	1	4	1800	1.00	1.00	1.00	1.00	SBS II	
17	17-19	1	4	1700	1.00	1.00	1.00	1.00	SBS II	
17	19A,20-8	1	4	1600	1.00	1.00	1.00	1.00	SBS II	
17	30-35	1	4	1500	1.00	1.00	1.00	1.00	SBS II	
17	35A,36	1	4	1500	1.00	1.00	1.00	1.00	SBS II	

EXHIBIT A-6

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI (Cont.)

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
17	37A,37-49	1	4	1400	1.00	1.00	1.00	1.00	SBS II	
17	50A,52-3	1	4	1300	1.00	1.00	1.00	1.00	SBS II	
17	59-60	1	4	1200	1.00	1.00	1.00	1.00	SBS II	
17	58A,62	1	4	1200	1.00	1.00	1.00	1.00	SBS II	
18	2	1	4	1700	1.00	1.00	1.00	1.00	SBS II	
20	4	1	4	2100	1.00	1.00	1.00	1.00	SBS II	
20	6-10	1	4	2400	1.00	1.00	1.00	1.00	SBS II	
20	14	1	4	2200	1.00	1.00	1.00	1.00	SBS II	
20	30-1	1	4	2200	1.00	1.00	1.00	1.00	SBS II	
20	32A,34A	1	4	2000	1.00	1.00	1.00	1.00	SBS II	
20	34-6	1	4	2000	1.00	1.00	1.00	1.00	SBS II	
20	38A	1	4	2000	1.00	1.00	1.00	1.00	SBS II	
21	1	1	4	1800	1.00	1.00	1.00	1.00	SBS II	
21	2	1	4	2000	1.00	1.00	1.00	1.00	SBS II	
21	3-6	1	4	2200	1.00	1.00	1.00	1.00	SBS II	
21	7-12	1	4	2400	1.00	1.00	1.00	1.00	SBS II	
22	1-10	1	9	2400	1.00	1.00	1.00	1.00	SBS II	
25	1-14	1	4	2800	1.00	1.00	1.00	1.00	SBS II	
26	36-40	9	9	3800	1.00	1.00	1.00	1.00	SBS I	Few details
26	42-6	9	9	3800	1.00	1.00	1.00	1.00	SBS I	Few details
27	3,4	1	4	3800	1.00	1.00	1.00	1.00	SBS II	
27	8	1	4	3900	1.00	1.00	1.00	1.00	SBS II	

EXHIBIT A-6

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI (Cont.)

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
31	2	1	4	4200	1.00	1.00	1.00	1.00	SBS I	
31	3,4	2	5	4200	1.00	1.00	1.00	1.00	SBS I	
31	12,14	9	9	4700	1.00	1.00	1.00	1.00	SBS I	Few details
31	13	9	9	4800	1.00	1.00	1.00	1.00	SBS I	Few details
31	15	9	9	4600	1.00	1.00	1.00	1.00	SBS I	Few details
31	16	9	9	4400	1.00	1.00	1.00	1.00	SBS I	Few details
32	A4-6	9	9	5000	1.00	1.00	1.00	1.00	SBS II	Few details
35	4	9	9	5800	1.00	1.00	1.00	1.00	SBS I	Few details
35	5,6	9	9	5900	1.00	1.00	1.00	1.00	SBS I	Few details
35	7,9	9	9	6000	1.00	1.00	1.00	1.00	SBS I	Few details
35	8	9	9	5700	1.00	1.00	1.00	1.00	SBS I	Few details
35	10	9	9	5400	1.00	1.00	1.00	1.00	SBS I	Few details
35	11-12	9	9	5500	1.00	1.00	1.00	1.00	SBS I	Few details
35	13-14	9	9	5600	1.00	1.00	1.00	1.00	SBS I	Few details
36	2,3,5	1	4	5800	1.00	1.00	1.00	1.00	SBS I	
36	6	1	2	5800	1.00	1.00	1.00	1.00	SBS I	
36	7	1	5	5800	1.00	1.00	1.00	1.00	SBS I	
36	15	1	4	5300	1.00	1.00	1.00	1.00	SBS I	
37	1	1	4	5200	1.00	.50	1.00	1.00	SBS II	
37	2	1	4	5300	1.00	1.00	1.00	1.00	SBS II	
37	4	2	4	5800	1.00	1.00	1.00	1.00	SBS II	
37	5,6	1	5	5800	1.00	1.00	1.00	1.00	SBS II	

EXHIBIT A-6

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI (Cont.)

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
37	7	2	9	5900	1.00	1.00	1.00	1.00	SBS II	
40	2B	1	5	6400	1.00	1.00	1.00	1.00	SBS II	
40	9	9	9	6400	1.00	1.00	1.00	1.00	SBS I	Few details
40	12	1	4	6500	1.00	1.00	1.00	1.00	SBS I	Few details
40	13	1	4	6500	1.00	.67	1.00	1.00	SBS I	
41	1	1	4	6400	1.00	1.00	1.00	1.00	SBS I	
41	3,6,8	1	4	6400	1.00	1.00	1.00	1.00	SBS I	
41	5	1	4	6400	1.00	1.00	1.00	1.00	SBS I	
41	9	1	4	6400	0	0	1.00	1.00	SBS I	
41	10	2	5	6400	0	0	1.00	1.00	SBS I	
42	3,4	1	4	6800	1.00	1.00	1.00	1.00	SBS I	
44 & 5	2,3	2	4	8200	0	0	1.00	1.00	SBS I	
44 & 5	4	2	4	8200	.25	.25	1.00	1.00	SBS I	
44 & 5	5	1	4	7800	.35	.35	1.00	1.00	SBS I	
48	1	1	4	8300	0	0	1.00	1.00	SBS II	Shielded from blast?
50	2	5	4	9500	.20	.20	.20	1.00	SBS I	
50	4	1	4	9500	0	0	0	--	SBS I	Few details
50	6-8	1	4	9500	0	0	0	--	SBS I	Few details
50	11	1	4	9500	0	0	0	--	SBS I	Few details
52	5B1-2	1	4	11500	0	0	0	--	SBS I	
52	10A2	2	5	11300	0	0	.75	--	SBS I	
56	1	1	4	15000	0	0	0	--	SBS IV & Wrk Pap	

EXHIBIT A-6

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI (Cont.)

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
58	16	1	5	19000	0	0	0	--	SBS Work. Pap.	
58	18	1	4	19000	0	0	0	--	SBS Work. Pap.	
70	2	1	4	8800	1.00	1.00	1.00	1.00	SBS II	
71	1-7	1	4	8800	1.00	1.00	1.00	1.00	SBS I	
82	1	1	9	10700	0	0	.05	--	SBS I	Few details
82	2,3	1	9	11300	0	0	.05	--	SBS I	Few details
82	4,5	1	9	11600	0	0	.05	--	SBS I	Few details
82	6,7	1	9	11800	0	0	.05	--	SBS I	Few details
89	6	1	4	16400	0	0	0	.50	SBS I	
91	5,6	1	9	19000	0	0	0	0	SBS II	
92	1	1	4	19000	0	.08	.10	--	SBS I	
92	2,3	1	4	19000	0	0	0	--	SBS I	

EXHIBIT A-7

MULTISTORY WOOD FRAME BUILDINGS AT HIROSHIMA

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
	87A	1	4	8000	1.00	1.00	1.00	1.00	SBS II	School
	109	1	4	7700	.94	1.00	1.00	1.00	SBS II	School
	113A	1	5	7600	1.00	1.00	1.00	1.00	SBS II	
114	A,B	1	5	8700	.13	.13	1.00	1.00	SBS II	School
	115	1	4	10400	.01	0	.01	1.00	SBS II	
116	E	1	4	9100	0	0	.04	1.00	SBS II	
116	G	1	4	9700	.04	0	.05	1.00	SBS II	
116	H,I	1	4	9300	0	.03	.03	1.00	SBS II	
	119	2	4	9900	0	0	0	1.00	SBS II	School
124	B,C	1	4	7600	1.00	1.00	1.00	1.00	SBS II	School
127	A	1	4	8500	0	0	1.00	1.00	SBS II	
130	E3	1	9	8500	1.00	1.00	1.00	1.00	BYD	
215	1,2	1	4	6900	1.00	1.00	1.00	1.00	BYD	School
215	3	1	4	6900	.50	.50	.50	1.00	BYD	School
	216	1	9	6600	1.00	1.00	1.00	1.00	BYD	2 buildings
	218	1	4	9700	0	0	0	1.00	BYD	School
222	1	1	9	8300	0	0	.50	1.00	BYD	School

EXHIBIT A-8

MULTISTORY WOOD FRAME BUILDINGS AT NAGASAKI

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
1	5	1	4	5800	1.00	1.00	1.00	1.00	SBS II	School
4	32	1	4	4500	1.00	1.00	1.00	1.00	SBS I	
5	2	1	5	3400	1.00	1.00	1.00	1.00	SBS I	
9	3,4	1	4	2600	1.00	1.00	1.00	1.00	SBS II	School
13	2	1	4	1100	1.00	1.00	1.00	1.00	SBS II	
19	1	1	4	1600	1.00	1.00	1.00	1.00	SBS II	
26	1N	1	4	1500	1.00	1.00	1.00	1.00	SBS I	
27	5-7	1	4	3800	1.00	1.00	1.00	1.00	SBS II	School
32	A2-3	9	9	5000	1.00	1.00	1.00	1.00	SBS II	School (few details)
36	20-1	1	4	5000	1.00	1.00	1.00	1.00	SBS I	
36	23	1	4	5100	1.00	1.00	1.00	1.00	SBS I	
38	4	1	4	6400	1.00	1.00	1.00	1.00	SBS II	School
42	2	1	4	6800	1.00	1.00	1.00	1.00	SBS II	School
48	2	1	4	8300	1.00	1.00	1.00	1.00	SBS II	School
48	4	1	4	8300	0	0	.75	1.00	SBS II	School
50	3	1	4	9700	0	0	0	1.00	SBS I	
50	5	1	4	9500	0	0	1.00	1.00	SBS I	Few details
50	9	1	4	9500	.25	0	1.00	1.00	SBS I	
50	10	1	4	9500	0	0	.50	1.00	SBS I	
52	6,6A,7	1	5	11500	0	0	0	--	SBS I	
52	23	1	4	9900	0	0	0	--	SBS I	
54	8,11	1	4	13500	0	0	0	.50	SBS I	

EXHIBIT A-8

MULTISTORY WOOD FRAME BUILDINGS AT NAGASAKI (Cont.)

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
58	1	1	4	20000	0	0	0	--	SBS Work. Pap.	
58	17	1	4	19000	0	0	0	--	SBS Work. Pap.	
80	1	1	4	10500	.15	.25	.25	1.00	SBS II	
84	4	1	4	12500	0	0	.18	1.00	SBS II	
87	1,2	1	4	14300	0	0	0	0	SBS I	Unspecified # of addit. minor bldgs.
91	2-4	1	9	19000	0	0	0	0	SBS II	School
EG W STA		1	4	30000	0	0	0	0	SBS Work. Pap.	

EXHIBIT A-9

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
	52	9	9	2800	1.00	1.00	1.00	1.00	SBS II	Damage too severe for detail analysis
	56	1	2	3800	1.00	1.00	1.00	1.00	SBS II	
	57	1	2	4200	1.00	1.00	1.00	1.00	SBS II	
	58	9	9	3900	1.00	1.00	1.00	1.00	SBS II	
	63	1	2	1800	1.00	1.00	1.00	1.00	SBS II	
	75N	1	2	6000	0	0	1.00	1.00	SBS II	
	75S	1	3	6000	0	0	1.00	1.00	SBS II	
	77	1	3	6400	1.00	1.00	1.00	1.00	SBS II	
	78	1	2	5800	.50	0	1.00	1.00	SBS II	
	81	6	3	5400	0	0	1.00	1.00	SBS II	4½-ft brick wall (non-load-bearing)
	83	6	3	3300	0	0	1.00	1.00	SBS II	Concrete filled columns
	87B	2	2	8000	0	0	1.00	1.00	SBS II	
91	A	2	3	14600	0	0	.05	--	BYD	4 buildings, little data
	94	2	2	1100	1.00	1.00	1.00	1.00	SBS II	
	98B	2	3	6700	0	0	1.00	1.00	SBS II	2nd story only (1st story concrete)
102	B	1	2	4900	.18	.20	1.00	1.00	SBS II	
102	C(N)	2	2	4900	1.00	.50	1.00	1.00	SBS II	North wing
	104	2	2	5000	.88	.88	1.00	1.00	SBS II	
	105	1	3	4000	0	0	1.00	1.00	SBS II	2nd story only (1st story concrete)
	107	2	2	3800	1.00	1.00	1.00	1.00	SBS II	
112	A	1	3	6500	0	0	1.00	1.00	SBS II	
112	B	2	3	6600	0	0	1.00	1.00	SBS II	

EXHIBIT A-9

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA (Cont.)

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
112	E	3	3	6600	.63	.63	1.00	1.00	SBS II	Very light steel frame
	118	3	2	9100	1.00	0	1.00	1.00	SBS II	Very light steel frame
	119ANX	2	2	9900	0	0	.25	1.00	SBS II	Annex to building 119
	120	1	2	5700	0	0	1.00	1.00	SBS II	
	124	2	2	7600	0	0	1.00	1.00	SBS II	
126	B(W)	2	2	8800	0	0	0	1.00	SBS II	West wing semi-circular
	C	2	2	8800	0	0	0	1.00	SBS II	Semi-circular
	128	1	2	5700	1.00	1.00	1.00	1.00	SBS II	
130	B	1	2	8200	0	0	1.00	1.00	BYD	
201	3	2	3	9200	0	0	.33	1.00	BYD	
213	2	2	3	10000	0	0	1.00	1.00	BYD	3 buildings
JSC	8	2	5	21500	0	0	.05	.25	SBS III & Notes	
JSC	30	2	3	20700	0	0	.15	.30	SBS III & Notes	
	37	2	3	20200	0	0	0	--	SBS III & Notes	
	59	2	3	21100	0	0	0	--	SBS III & Notes	
AP	1	2	5	13900	0	0	0	--	SBS Work. Pap.	

EXHIBIT A-10

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
1	7A	4	2	5800	0	0	1.00	1.00	SBS II	
4	1	4	3	5500	.50	0	1.00	1.00	SBS I	
4	2	1	3	5400	0	0	1.00	1.00	SBS I	
4	11	2	3	4400	.80	.40	1.00	1.00	SBS I	
4	25	2	2	4100	1.00	1.00	1.00	1.00	SBS I	
4	35	2	3	4100	1.00	.95	1.00	1.00	SBS I	
10	8	4	2	3900	.80	.80	1.00	1.00	SBS II	
26	5	1	2	2500	1.00	1.00	1.00	1.00	SBS I	
26	10A	1	2	3200	1.00	1.00	1.00	1.00	SBS I	
26	10B	1	2	3200	1.00	1.00	1.00	1.00	SBS I	
26	18	1	2	3900	.50	.20	1.00	1.00	SBS I	
26	25B	4	2	4300	0	1.00	1.00	1.00	SBS I	
26	32	4	2	4700	.60	.85	1.00	1.00	SBS I	Listed in TM-4 as Group 10
31	1	1	2	4200	1.00	1.00	1.00	1.00	SBS I	
31	7	1	2	4300	0	0	1.00	1.00	SBS I	
35	2	1	3	5600	0	0	1.00	1.00	SBS I	
38	1	1	2	6300	.10	.10	.91	1.00	SBS II	
40	2A	1	2	6400	.30	.15	.80	1.00	SBS I	
40	11(W)	1	2	6500	1.00	1.00	1.00	1.00	SBS I	West wing
44 & 5	6	1	2	7400	0	0	1.00	1.00	SBS I	
52	1A2	2	2	12200	0	0	.50	--	SBS I	
52	1C1	1	2	12200	0	0	0	--	SBS I	

EXHIBIT A-10

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI (Cont.)

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
52	8A	1	3	11300	0	0	.65	1.00	SBS I	
52	8B	1	3	11400	0	0	.72	1.00	SBS I	
52	9B	1	3	11500	0	0	.39	.39	SBS I	
52	10A1	1	3	11300	0	0	.05	--	SBS I	
52	12B	4	2	11600	0	0	0	--	SBS I	
52	12C1-5	1	2	11500	0	0	0	--	SBS I	
52	12C6	1	2	11400	.12	.60	.60	.60	SBS I	
52	12C7	1	2	11400	0	0	0	.50	SBS I	
52	12J	1	2	11800	0	0	0	--	SBS I	
52	12F	1	2	11000	0	0	0	--	SBS I	
55	2	2	2	14600	0	0	0	--	SBS I	
58	3	1	2	20000	0	0	0	--	SBS Work. Pap.	
58	15	2	3	19000	0	0	0	--	SBS Work. Pap.	
58	28-30	1	3	18000	0	0	0	--	SBS Work. Pap.	
58	37-8	1	2	17000	0	0	0	--	SBS Work. Pap.	
89	3-5	1	2	16400	0	0	0	.50	SBS I	

EXHIBIT A-11

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS (CRANES $\leq$ 25 TONS) AT HIROSHIMA

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
JSC	7	2	3	21300	0	0	.25	.25	SBS III & Notes	
JSC	11	2	5	21500	0	0	.12	--	SBS III & Notes	
JSC	71	2	5	22400	0	0	.30	.40	SBS III & Notes	

EXHIBIT A-12

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
4	4	2	3	5100	1.00	1.00	1.00	1.00	SBS I	
4	5	2	3	5000	.90	.50	1.00	1.00	SBS I	
4	5A	2	3	4800	.90	1.00	1.00	1.00	SBS I	
4	10	2	3	4600	1.00	1.00	1.00	1.00	SBS I	
4	20	2	3	5100	1.00	1.00	1.00	1.00	SBS I	
4	21	2	2	4900	1.00	1.00	1.00	1.00	SBS I	
4	22	2	2	4500	.90	1.00	1.00	1.00	SBS I	
4	23	2	2	4200	1.00	1.00	1.00	1.00	SBS I	
26	3	1	2	2000	1.00	1.00	1.00	1.00	SBS I	
26	4	1	2	2000	1.00	1.00	1.00	1.00	SBS I	
26	6,7	1	2	2700	1.00	1.00	1.00	1.00	SBS I	
26	8	1	2	3000	1.00	1.00	1.00	1.00	SBS I	
26	9	1	2	3100	1.00	0	1.00	1.00	SBS I	
26	11B	1	2	3300	0	1.00	1.00	1.00	SBS I	
26	12A	1	2	3300	1.00	1.00	1.00	1.00	SBS I	
26	15	1	2	3700	.75	1.00	1.00	1.00	SBS I	
26	16	1	2	3900	1.00	1.00	1.00	1.00	SBS I	
26	22	1	2	3900	.05	.05	1.00	1.00	SBS I	
26	25A	1	2	4300	.80	1.00	1.00	1.00	SBS I	
26	41	1	2	4300	0	0	1.00	1.00	SBS I	
31	9	1	2	4500	0	1.00	1.00	1.00	SBS I	
31	11	1	2	4600	.02	.80	1.00	1.00	SBS I	

EXHIBIT A-12

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI (Cont.)

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
52	12A2-3	1	3	11700	0	0	0	--	SBS I	
52	12A5-6	1	3	11700	0	0	0	--	SBS I	
55	4	2	2	14800	0	0	.05	--	SBS I	
55	6	1	2	15500	0	0	.05	.25	SBS I	
55	7	1	2	15800	0	0	.05	.25	SBS I	Damage repaired at time of survey
57	1,2	1	2	17500	0	0	.05	--	SBS I	

EXHIBIT A-13

MULTISTORY HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
	16	1	1	2400	0	0	1.00	1.00	SBS II	
	46	4	1	2000	1.00	1.00	1.00	1.00	SBS II	

EXHIBIT A-14

MULTISTORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
4	7,8	2	3	5000	0	0	1.00	1.00	SBS I	
26	26	1	2	4300	1.00	1.00	1.00	1.00	SBS I	
25	27	4	1	4500	.05	1.00	1.00	1.00	SBS I	
50	1	1	2	9700	0	0	1.00	1.00	SBS I	Part 1-story/part 2-story
52	23A,C2	1	3	12000	0	0	0	--	SBS I	
52	9A	1	3	11500	0	0	.19	.40	SBS I	
52	12A1,4	1	3	11700	0	0	0	--	SBS I	
52	12D1-3	1	2	11400	0	0	0	--	SBS I	
52	12K,M	1	2	11800	0	0	0	--	SBS I	
52	15E	2	2	11000	0	0	0	--	SBS I	Partially disassembled before attack
52	16B	1	2	10800	0	0	.38	.50	SBS I	
54	1	1	2	13800	0	0	.09	.50	SBS I	
54	2	1	2	13500	0	0	0	.50	SBS I	
54	3	2	1	13700	0	0	.41	1.00	SBS I	
54	5	1	2	13600	0	0	.15	.50	SBS I	
54	7	1	2	13600	0	0	.40	.50	SBS I	
54	9	1	2	13600	0	0	.15	.50	SBS I	
54	10	1	2	13600	0	0	.50	.50	SBS I	
55	1	1	2	14600	0	0	0	.05	SBS I	
55	10	1	2	15100	0	0	0	.25	SBS I	
89	1,2	1	2	16400	0	0	0	.50	SBS I	

EXHIBIT A-15

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS (CRANES > 25 TONS) AT HIROSHIMA

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
None										

EXHIBIT A-16

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS (CRANES > 25 TONS) AT NAGASAKI

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
26	11A	1	2	3200	1.00	1.00	1.00	1.00	SBS I	
26	11C	1	2	3400	1.00	1.00	1.00	1.00	SBS I	
26	23	1	2	4100	.66	1.00	1.00	1.00	SBS I	
31	8	1	2	4400	.05	.80	1.00	1.00	SBS I	
36	8	1	3	5600	.05	0	1.00	1.00	SBS I	
36	16	1	3	5000	0	.10	1.00	1.00	SBS I	

EXHIBIT A-17

REINFORCED CONCRETE FRAME BUILDINGS AT HIROSHIMA

BUILDING		TYPE		DISTANCE	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof	(Feet)	Wall	Roof	Superf	Glass		
	18-20	--	--	1000	--	--	--	1.00	SBS II	
	21,23	--	--	1200	--	--	--	1.00	SBS II	
	22	--	--	1100	--	--	--	1.00	SBS II	
	24	--	--	1300	--	--	--	1.00	SBS II	
	25	--	--	1400	--	--	--	1.00	SBS II	
	26	--	--	2300	--	--	--	1.00	SBS II	
	30	--	2	5500	--	1.00	--	1.00	SBS II	
	31	--	--	4900	--	--	--	1.00	SBS II	
	32F	--	--	4600	--	--	--	1.00	SBS II	
	32G	--	--	4800	--	--	--	1.00	SBS II	
	33	--	--	5300	--	--	--	1.00	SBS II	
	39	--	--	2500	--	--	--	1.00	SBS II	
	42	--	3	1600	--	1.00	--	1.00	SBS II	
	44	--	--	1800	--	--	--	1.00	SBS II	
	59	--	--	4100	--	--	--	1.00	SBS II	
	60	--	4	3000	--	1.00	--	--	SBS II	
	61	--	--	3300	--	--	--	1.00	SBS II	
	64	--	--	4900	--	--	--	1.00	SBS II	
	85	--	--	3300	--	--	--	1.00	SBS II	
	93	--	--	1400	--	--	--	1.00	SBS II	
	95	--	--	1200	--	--	--	1.00	SBS II	
	101	--	--	1800	--	--	--	1.00	SBS II	

EXHIBIT A-17

REINFORCED CONCRETE FRAME BUILDINGS AT HIROSHIMA (Cont.)

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
	108	--	2	5900	--	1.00	--	1.00	SBS II	
	113C	--	--	7400	--	--	--	.75	SBS II	
	113D	--	--	7600	--	--	--	.75	S3S II	
126	A	--	--	8700	--	--	--	1.00	SBS II	
126	B,E	--	--	8800	--	--	--	1.00	SBS II	
	129	--	--	5600	--	--	--	1.00	SBS II	
JSC	20	--	--	21000	--	--	--	.25	SBS III & Notes	

EXHIBIT A-18

REINFORCED CONCRETE FRAME BUILDINGS AT NAGASAKI

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
1	7	--	--	5800	--	--	--	1.00	SBS II	
4	3	--	--	5400	--	--	--	1.00	SBS I	
4	13	--	--	4300	--	--	--	1.00	SBS I	
4	18	--	--	5500	--	--	--	1.00	SBS I	
4	19	--	3	5500	--	0	--	--	SBS I	
4	24	--	3	4100	--	1.00	--	1.00	SBS I	
4	28	--	--	3900	--	--	--	1.00	SBS I	
4	35	--	2	3900	--	.05	--	1.00	SBS I	
7	2	--	--	4800	--	--	--	1.00	SBS II	
8	1	--	--	2300	--	--	--	1.00	SBS II	
10	3	--	--	3700	--	--	--	1.00	SBS II	
10	3A	--	--	3700	--	--	--	1.00	SBS II	Annex
14	1	--	--	1900	--	--	--	1.00	SBS II	
15	3	--	--	2200	--	--	--	1.00	SBS II	
16	1,2	--	--	1700	--	--	--	1.00	SBS II	
17	12,13A	--	--	1700	--	--	--	1.00	SBS II	
17	14,29	--	--	1700	--	--	--	1.00	SBS II	
17	50-1	--	--	1700	--	--	--	1.00	SBS II	
17	60A	--	--	1700	--	--	--	1.00	SBS II	
17	61	--	--	1700	--	--	--	1.00	SBS II	
18	1	--	4	1500	--	1.00	--	1.00	SBS II	
20	1-3	--	--	2000	--	--	--	1.0C	SBS II	

EXHIBIT A-18

REINFORCED CONCRETE FRAME BUILDINGS AT NAGASAKI (Cont.)

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
20	5	--	--	2100	--	--	--	1.00	SBS II	
20	11-12	--	--	2400	--	--	--	1.00	SBS II	
20	13	--	--	2200	--	--	--	1.00	SBS II	
20	15,17-18	--	--	2200	--	--	--	1.00	SBS II	
20	16	--	--	2100	--	--	--	1.00	SBS II	
20	19-20	--	--	2300	--	--	--	1.00	SBS II	
20	24-5	--	--	2500	--	--	--	1.00	SBS II	
20	26	--	--	2400	--	--	--	1.00	SBS II	
20	29	--	--	2200	--	--	--	1.00	SBS II	
20	32	--	--	2100	--	--	--	1.00	SBS II	
20	33,37-38	--	--	1800	--	--	--	1.00	SBS II	
26	1S,2	--	--	1500	--	--	--	1.00	SBS I	1S in reg. reflection region
26	12B	--	--	3300	--	--	--	1.00	SBS I	
26	14	--	--	3500	--	--	--	1.00	SBS I	
26	20	--	--	3900	--	--	--	1.00	SBS I	
26	21	--	--	4000	--	--	--	1.00	SBS I	
26	24	--	2	4100	--	0	--	1.00	SBS I	
26	28	--	2	4700	--	1.00	--	1.00	SBS I	
26	31	--	--	4700	--	--	--	1.00	SBS I	
26	29-30	--	--	4600	--	--	--	1.00	SBS I	
26	33	--	2	4700	--	1.00	--	1.00	SBS I	
26	34-5	--	--	4800	--	--	--	1.00	SBS I	

EXHIBIT A-18

REINFORCED CONCRETE FRAME BUILDINGS AT NAGASAKI (Cont.)

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
27	1	--	--	3700	--	--	--	1.00	SBS II	
27	2	--	--	3800	--	--	--	1.00	SBS II	
31	10W	--	5	4400	--	1.00	--	1.00	SBS I	
38	2-3	--	--	6300	--	--	--	1.00	SBS II	
48	5	--	--	8300	--	--	--	1.00	SBS II	
51	1	--	--	3600	--	--	--	1.00	SBS I	
52	3	--	2	11700	--	0	--	.50	SBS I	
52	5A	--	2	11500	--	0	--	1.00	SBS I	
52	18A,B	--	--	10200	--	--	--	.30	SBS I	
52	19A,B	--	--	10200	--	--	--	.60	SBS I	
52	20	--	--	10100	--	--	--	.70	SBS I	
52	22	--	--	10000	--	--	--	.65	SBS I	
54	4	--	--	13700	--	--	--	1.00	SBS I	
54	5	--	--	13700	--	--	--	.50	SBS I	
73	1	--	--	9800	--	--	--	.40	SBS II	
73	2	--	2	9800	--	0	--	1.00	SBS II	
83	1	--	4	12400	--	0	--	.95	SBS II	
83	2	--	--	12400	--	--	--	.50	SBS II	
83	3	--	--	12400	--	--	--	.95	SBS II	
83	5	--	--	12400	--	--	--	1.00	SBS II	

EXHIBIT A-19

COMPOSITE AND OTHER STRUCTURES AT HIROSHIMA

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
98	A	--	3	6400	--	0	--	1.00	SBS II	
102	C(S)	--	4	4900	--	.19	--	1.00	SBS II	
102	122	--	--	6400	--	--	--	1.00	SBS II	
WFP	8	--	--	9200	--	--	--	1.00	SBS III	

EXHIBIT A-20

COMPOSITE AND OTHER STRUCTURES AT NAGASAKI

BUILDING		TYPE		DISTANCE (Feet)	DAMAGE				SOURCE	COMMENTS
Group	No.	Wall	Roof		Wall	Roof	Superf	Glass		
5	1	--	5	3500	--	1.00	--	1.00	SBS I	Brick with wood columns
7	1	--	--	4800	--	--	--	1.00	SBS II	Brick & concrete
20	23	--	--	2500	--	--	--	1.00	SBS II	Regular reflection region (hill)
40	14	--	--	6500	--	--	--	1.00	SBS I	
44 & 5	1	--	--	8200	--	--	--	1.00	SBS I	
52	1C2	--	2	12200	--	0	--	--	SBS I	Steel & brick
52	2A2,C1	--	4	12000	--	0	--	--	SBS I	Steel, brick & wood

EXHIBIT A-21

BUILDINGS NOT INCLUDED IN DATA FILES
Reinforced Concrete Frame

HIROSHIMA	NAGASAKI	
Bldg. No.	Group	Bldg. No.
1,2	4	36B
6	5	6
8	32	A1
9	32	B
11	35	3
12	36	10
27	55	3
28	55	8,9
32A,B,D,E,H	55	11,12
38	84	5
40,41	91	1
43	94	1-3
47-51		
62		
65		
67		
70		
74		
76		
79		
86		
96		
100		
116A,B,C,F		
121		
132-5		

EXHIBIT A-22

BUILDINGS WITH SBS DAMAGE TABLES

HIROSHIMA

Bldg. No.	Reason for Exclusion
71	Fire damage
73	Fire damage

NAGASAKI

Group	Bldg. No.	Reason for Exclusion
4	8A	Not a building
13	4	Underground structure
26	13	H.E. damage
26	17	Not a building
26	19	H.E. damage
35	1	Fire damage
36	1	Fire damage
36	4	Not a building
40	1R	Fire damage
40	4-6	Not buildings
42	1	Fire damage
48	3	H.E. damage
52	2A4	Composite (steel frame, wood & brick)
52	12E1-3	H.E. damage
52	12F	H.E. damage
52	12G1-4	H.E. damage
52	12H1-5	H.E. damage
52	14	H.E. damage
52	15A1-2	H.E. damage
52	15B,C	H.E. damage
52	15D	H.E. damage
52	16A	H.E. damage
52	17A1-2	H.E. damage
52	17B,C	H.E. damage
52	17D	H.E. damage
54	12	H.E. damage
55	5	Not a building
72	1	Fire damage
72	2	Fire damage
81	1	Fire damage
81	2	Fire damage
81	4	Bldg. being taken down when inspected
81	5	Not a building

APPENDIX B

STATISTICAL ANALYSIS RESULTS

TABLE OF CONTENTS

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II. WOOD FRAME BUILDINGS B-110

III. LIGHT STEEL FRAME BUILDINGS B-194

IV. HEAVY STEEL FRAME BUILDINGS B-254

V. LIGHT AND HEAVY STEEL FRAME BUILDINGS B-306

APPENDIX B

STATISTICAL ANALYSIS RESULTS

The purpose of this appendix is to present the analysis results for every structure classification, subclassification, and damage criteria examined in the analysis phase of the efforts. The methodology used in these analyses is described in Section IV of the main body of the report. Throughout these results, the Cumulative Log Normal Damage Law and a yield of 12 Kt for the Hiroshima weapon are assumed.

The format used in each of the cases examined is to present a series of eight graphs. The first two graphs show the damage versus distance data for the buildings under consideration at Hiroshima and Nagasaki, respectively. The next two graphs show the effect of the Specified Damage Fraction on the values of R_{50} and β_R that are derived from these data. The next graph shows the effect of the Specified Damage Fraction on the values of P_{50} and β_P that are derived from the combined data, where the combination is done through the mechanism of calculated peak pressure. The sixth graph shows the 0.5 and 0.9 confidence level regions for the true values of P_{50} and β_P that are derived using the Unspecified Damage Fraction concept. The last two graphs show the 0.5 and 0.9 confidence regions for the true values of R_{50} and β_R that are derived from the direct damage-distance data for Hiroshima and Nagasaki and compares the confidence regions that are inferred from the combined damage-calculated peak pressure data.

Figures 1 through 13 deal with the cases involving Masonry Load-Bearing-Wall Buildings. Figures 14 through 23 deal with the Wood Frame Buildings. Figures 24 through 30 deal with the Light Steel Frame Buildings. Figures 31 through 36 deal with the Heavy Steel Frame Buildings. Figures 37 through 39 deal with the combined Light and Heavy Steel Frame Buildings and Figure 40 deals with glass breakage.

I. MASONRY LOAD-BEARING-WALL BUILDINGS

The data base includes 144 Masonry Load-Bearing-Wall Buildings, of which 82 were at Hiroshima and 62 were at Nagasaki. The breakdown of the number of these buildings according to Single-Story or Multistory and wall thickness classifications is as follows:

WALL TYPE	NUMBER OF BUILDINGS			
	SINGLE-STORY		MULTISTORY	
	Hiro	Naga	Hiro	Naga
5	11	3	2	0
6	11	17	3	3
7	12	0	9	0
8	3	2	5	0
9	12	30	14	7
TOTAL	49	52	33	10

Note that the thicker wall types (7 and 8) are relatively more scarce than the thin types (5 and 6). Nagasaki buildings are distributed particularly poorly, with nearly all the identifiable buildings having a wall thickness of 12 to 14 inches.

The breakdown by roof type is as follows:

ROOF TYPE	NUMBER OF BUILDINGS			
	SINGLE-STORY		MULTISTORY	
	Hiro	Naga	Hiro	Naga
1	3	2	3	0
2	16	14	1	0
3	3	4	0	4
4	22	21	26	4
5	4	11	2	2
9	1	0	1	0
TOTAL	49	52	33	10

The Single-Story Buildings are obviously the more numerous and thus permit the greatest subdivision by types of walls and roofs. The agreement amont the β_p's is fairly good for all the sets except the Quick Failing Roof Covering Material/Superficial Damage. The β_p's correspond to damage-distance sigmas (σ_d's) of about 26 ± 4. The Quick Failing case is obviously a bad data set as evidenced by only five data points within one sigma of the mean pressure. Thus, the MLE values are highly suspect.

The Multistory Buildings are isolated into only two sets because of insufficient data. And even these sets are highly suspect, because only two or three data points are near the mean and the value of β_p is very much lower than for the Single-Story Buildings.

The Masonry Load-Bearing-Wall Buildings are also isolated by thickness of the exterior walls, and Structural Damage to walls is examined. The thin wall case includes thicnesses of 7 to 14 inches (Wall Types 5 and 6), and the thick wall case includes thicknesses of 17 to 27 inches (Wall Types 7 and 8). It was not possible to isolate Multistory Buildings by wall type, but a combined Single-Story and Multistory case as well as Single-Story alone were included to give some idea of the effect of multiple stories.

The thin wall data sets give fairly consistent results with σ_d's of .28-.30, but the thick wall sets are, unfortunately, somewhat inadquate with only four points near the mean, thus giving bad results on the β_p values. Note also the confidence bounds for β_p in these data sets are quite large in comparison to the better data sets.

In addition, the distribution of roof types between steel truss (2 and 3) and wood truss (4 and 5) is fairly good for the Single-Story Buildings but poor for the Multistory Buildings. However, the number of buildings with quick failing roof covering material is quite small (3 and 5).

A summary table of the cases examined with some of the key observations is shown on the following page.

SUMMARY OF MASONRY LOAD-BEARING-WALL BUILDINGS

	M.L.E.		MAX 90% CONF. LIM.		DATA POINTS TOTAL		DATA POINTS ± SIGMA	
	P_{50}	β_P	P_{50}	β_P	H	N	H	N
A. SINGLE-STORY								
1. Structural	2.72	.38	2.25-3.2	.25-.61	49	52	29	10
2. Structural Wall	3.52	.42	2.95-4.3	.28-.66	49	52	15	17
3. Structural Roof								
a. Steel	3.45	.43	2.5 -4.8	.24-.94	19	18	6	6
b. Wood	2.45	.35	1.95-3.0	.21-.69	26	32	12	6
4. Superficial								
a. All	2.11	.395	1.7 -2.5	.26-.64	49	52	25	14
b. Slow Roof	2.03	.47	1.55-2.55	.30-.80	38	35	17	6
c. Quick Roof	1.93	.18	1.60-2.5	.09-.57	7	15	3	2
B. MULTISTORY								
1. Structural	3.55	.17	2.85-4.85	.05-.46	33	10	3	0
2. Structural Wall	4.07	.13	3.2 -5.3	.04-.44	33	10	2	0
C. STRUCTURAL WALL								
1. Any Story								
a. Thin Wall	3.17	.45	2.5 -4.0	.28-.85	27	23	15	8
b. Thick Wall	4.37	.18	3.6 -6.0	.05-.54	29	2	3	1
2. Single Story								
a. Thin Wall	3.11	.49	2.3 -4.1	.29-1.05	22	20	16	8
b. Thick Wall	4.34	.24	3.2 -8.4	.06-.94	15	2	2	2

FIGURE 1a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
STRUCTURAL DAMAGE CRITERIA

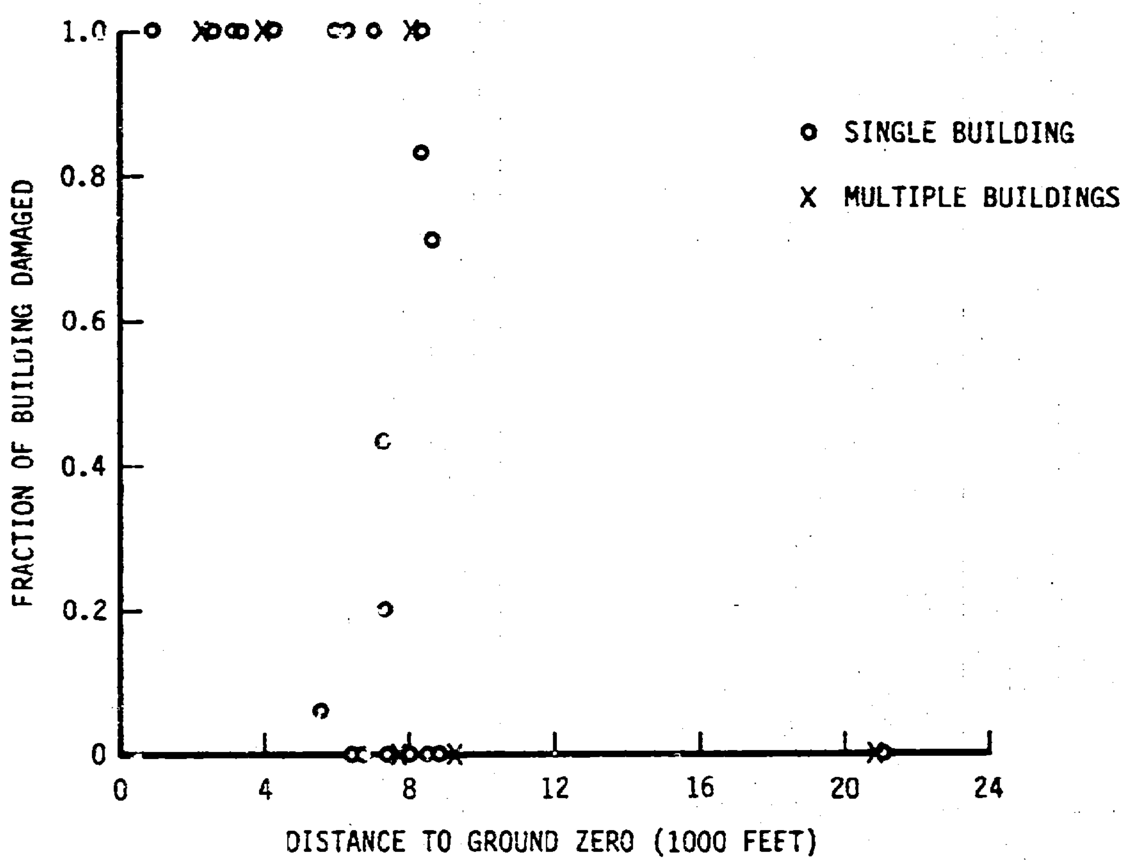


FIGURE 1b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE CRITERIA

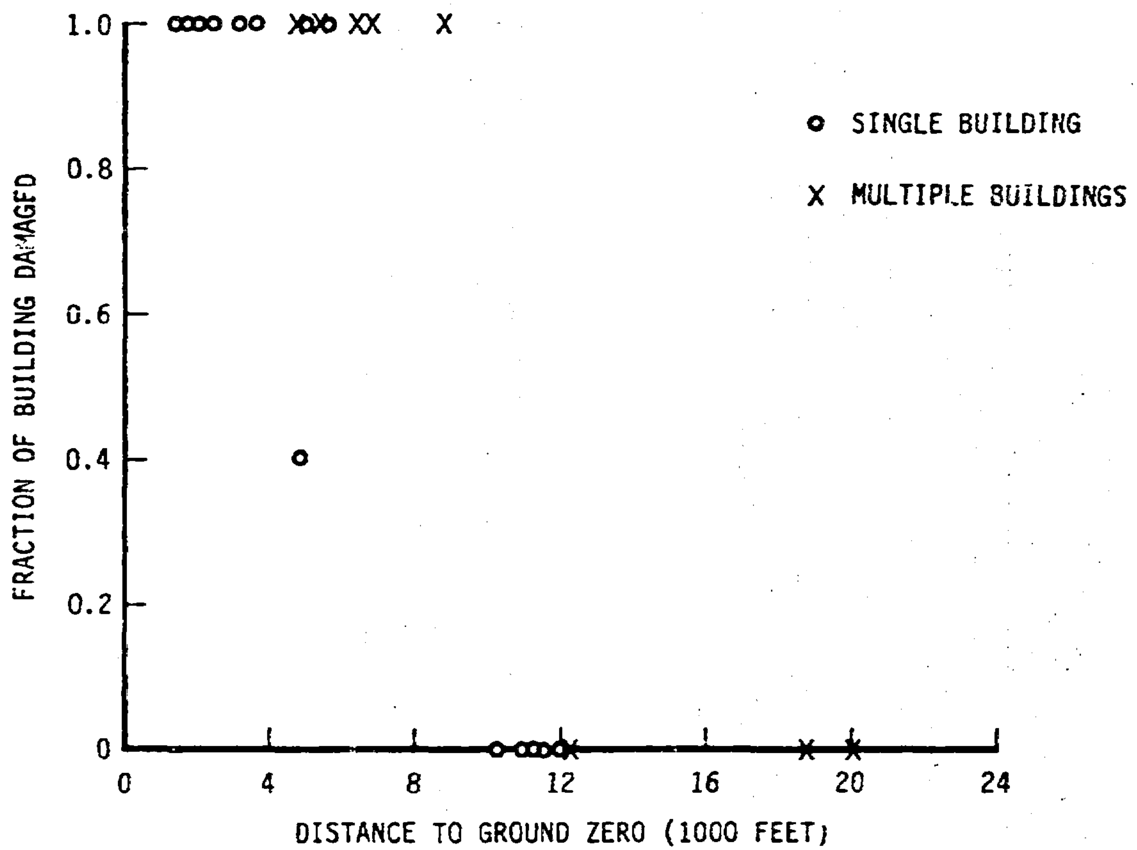
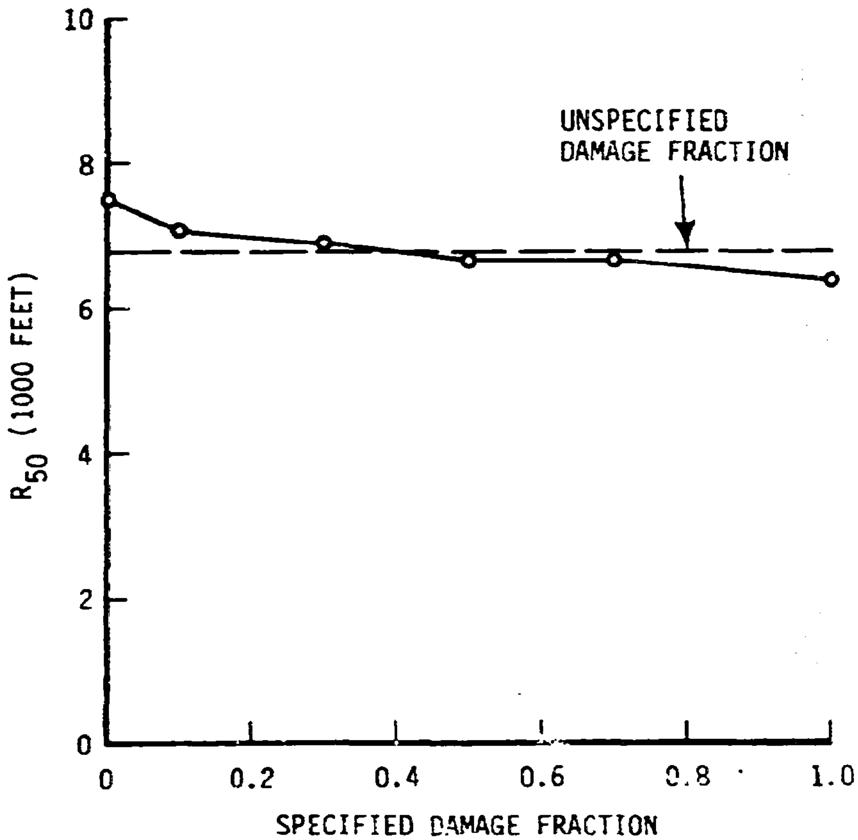


FIGURE 1c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

STRUCTURAL DAMAGE CRITERIA



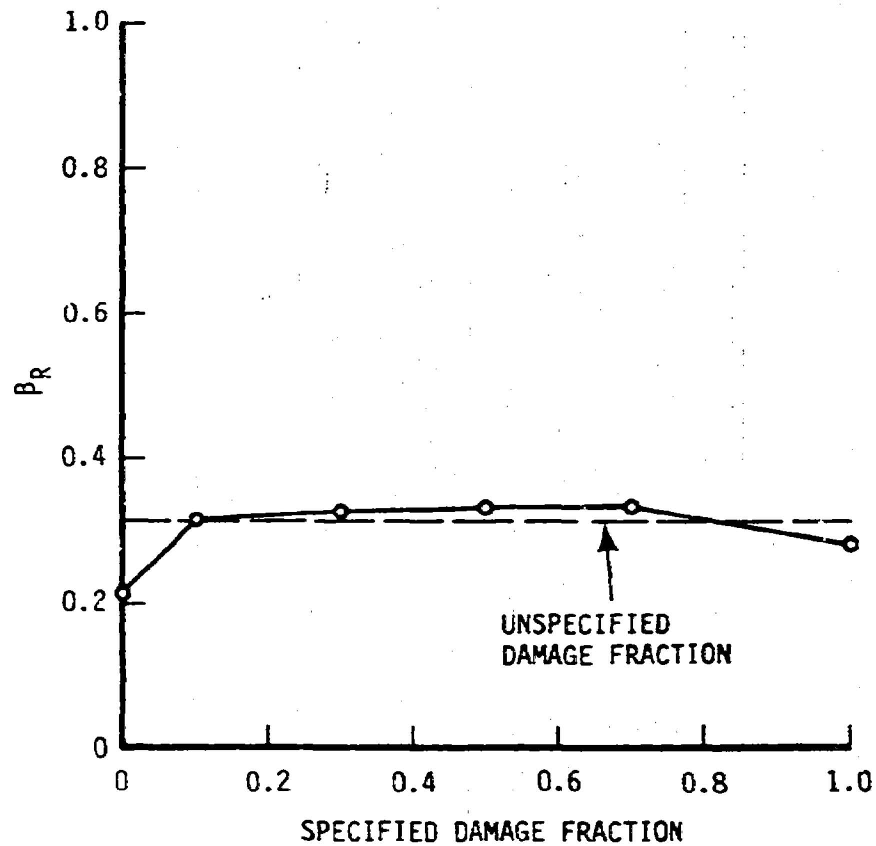
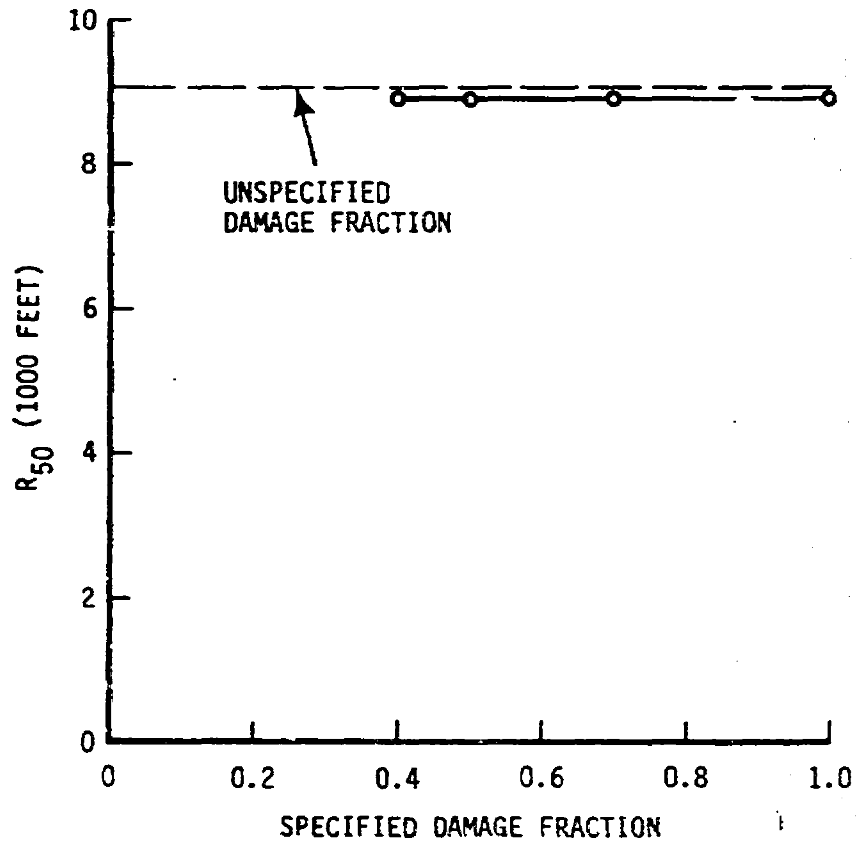


FIGURE 1d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE CRITERIA



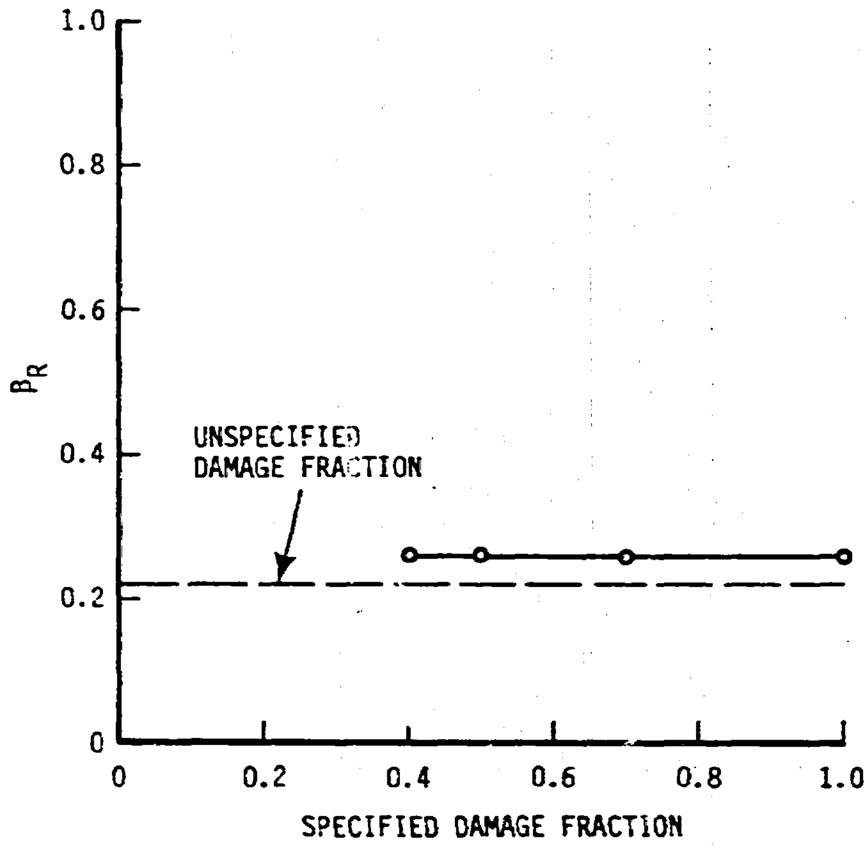


FIGURE 1e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS
STRUCTURAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT

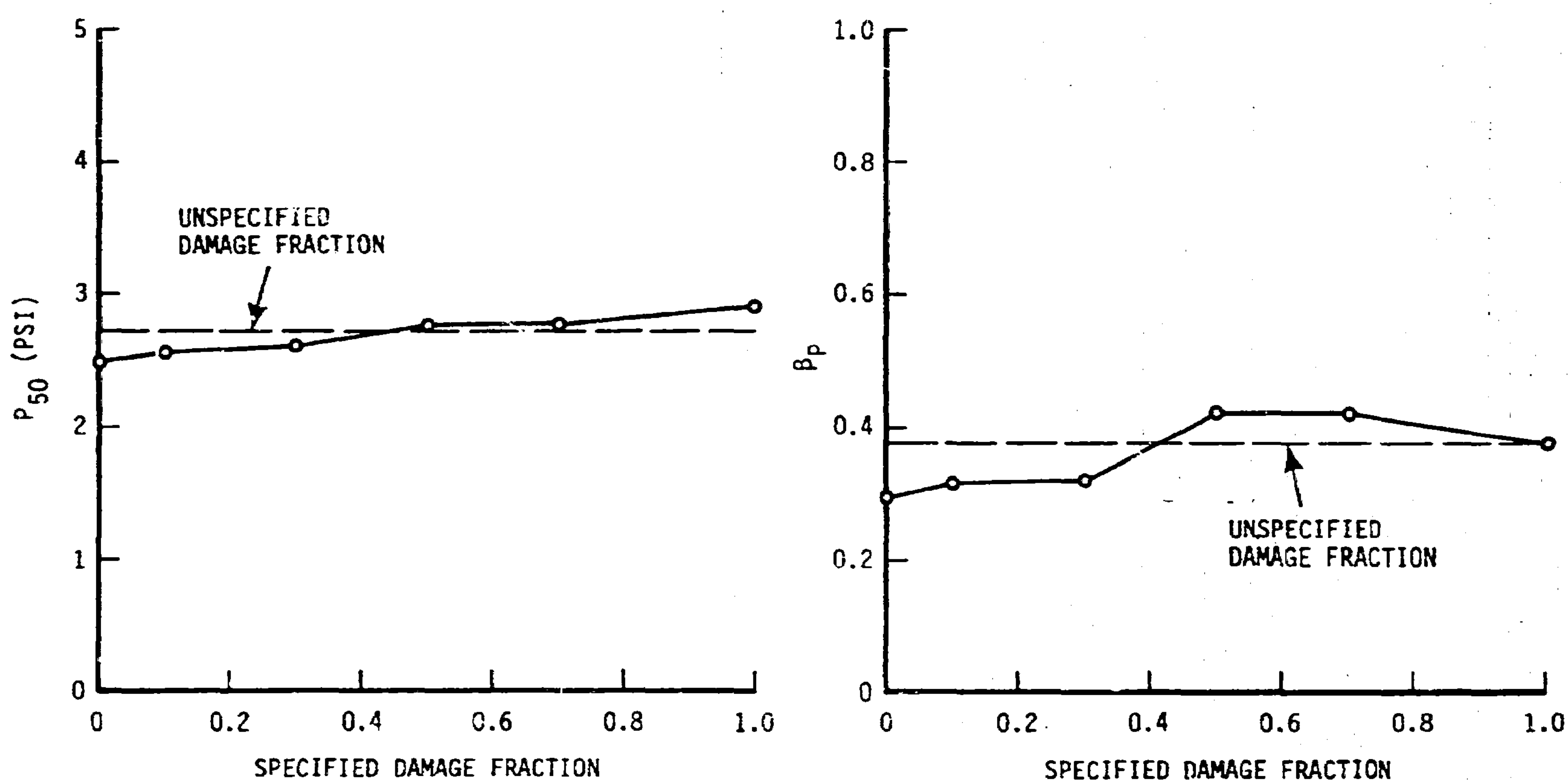


FIGURE 1f

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS
STRUCTURAL DAMAGE CRITERIA

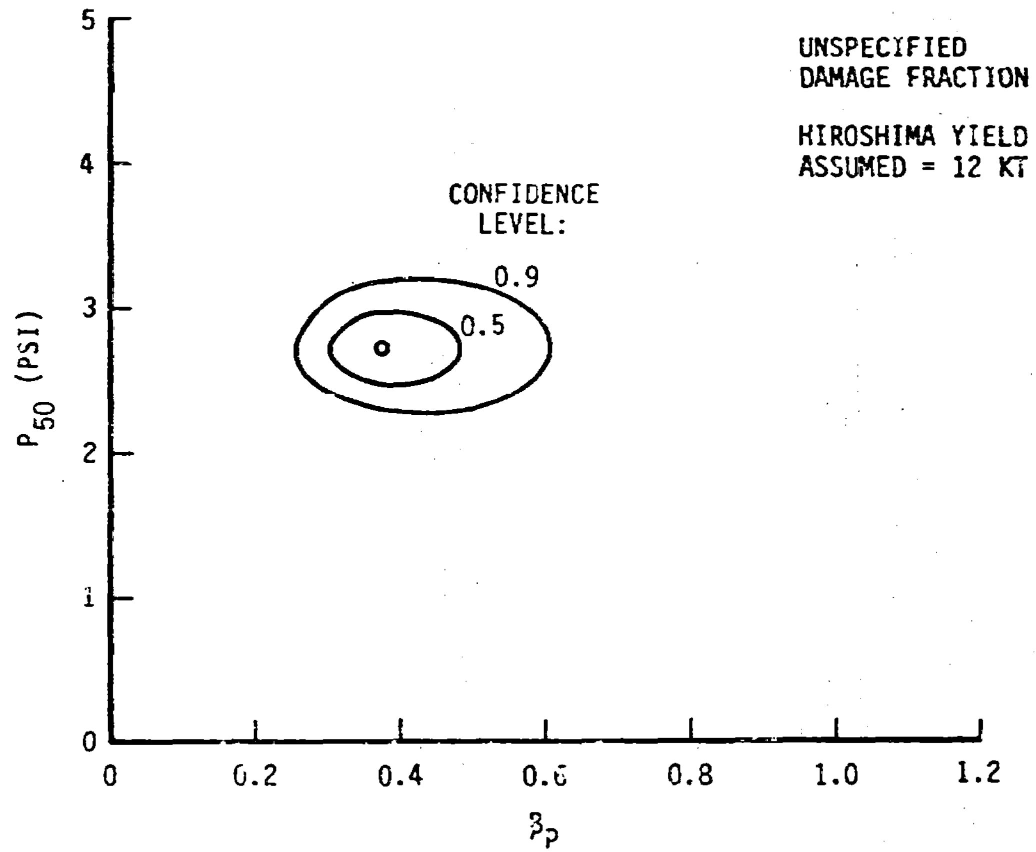


FIGURE 1g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

STRUCTURAL DAMAGE CRITERIA

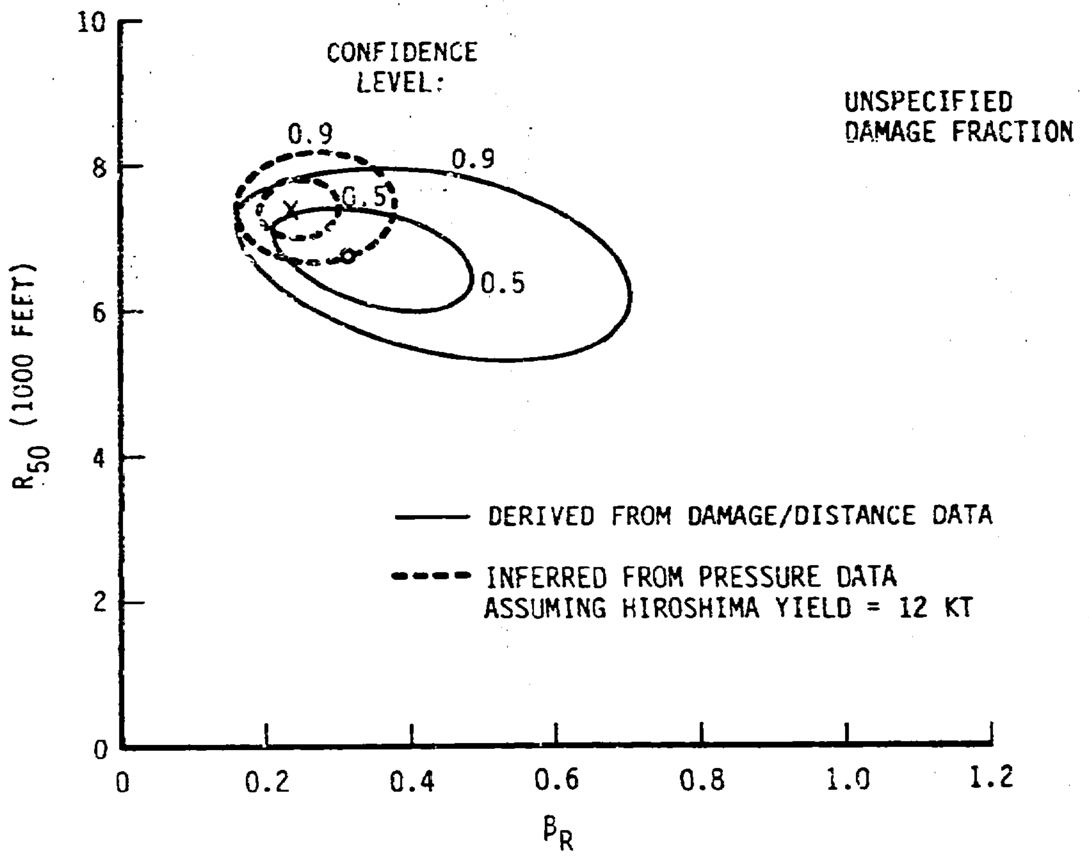


FIGURE 1h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE CRITERIA

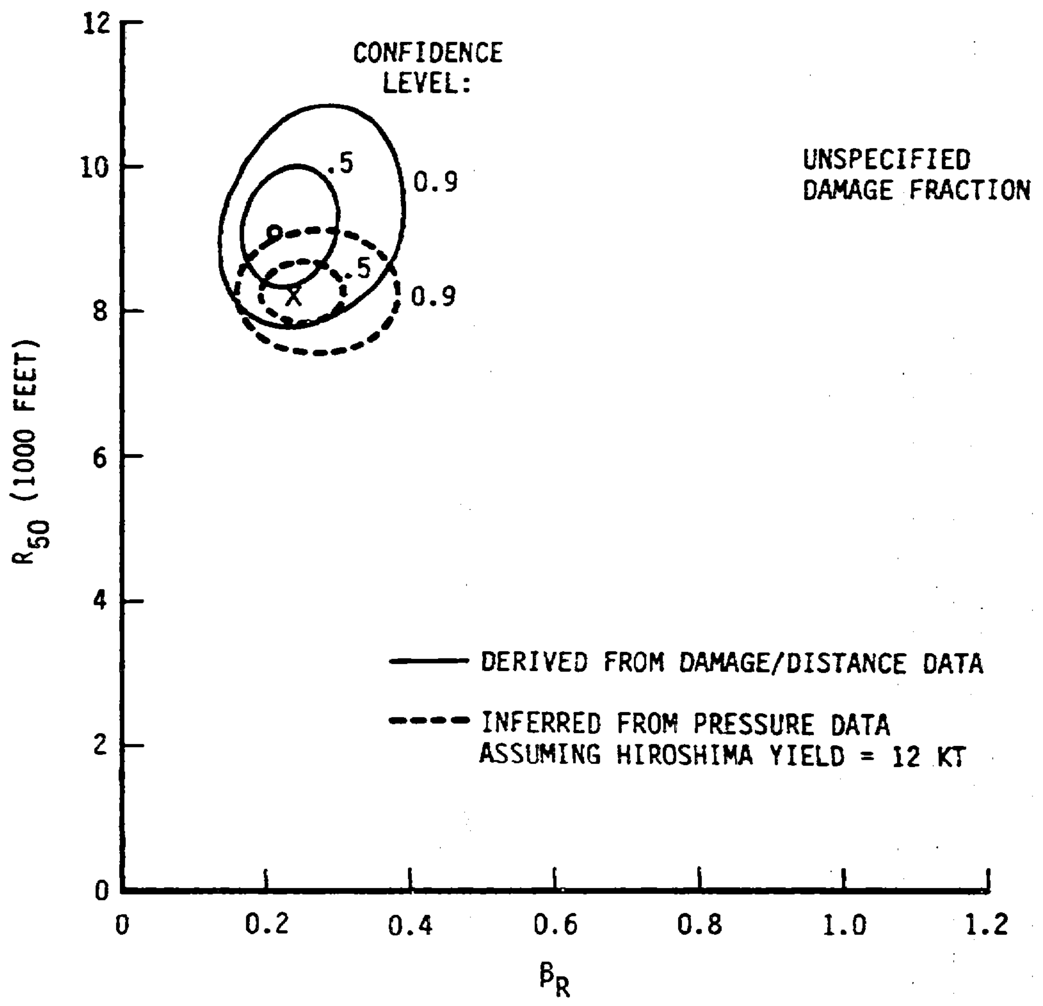


FIGURE 2a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
STRUCTURAL DAMAGE TO WALLS

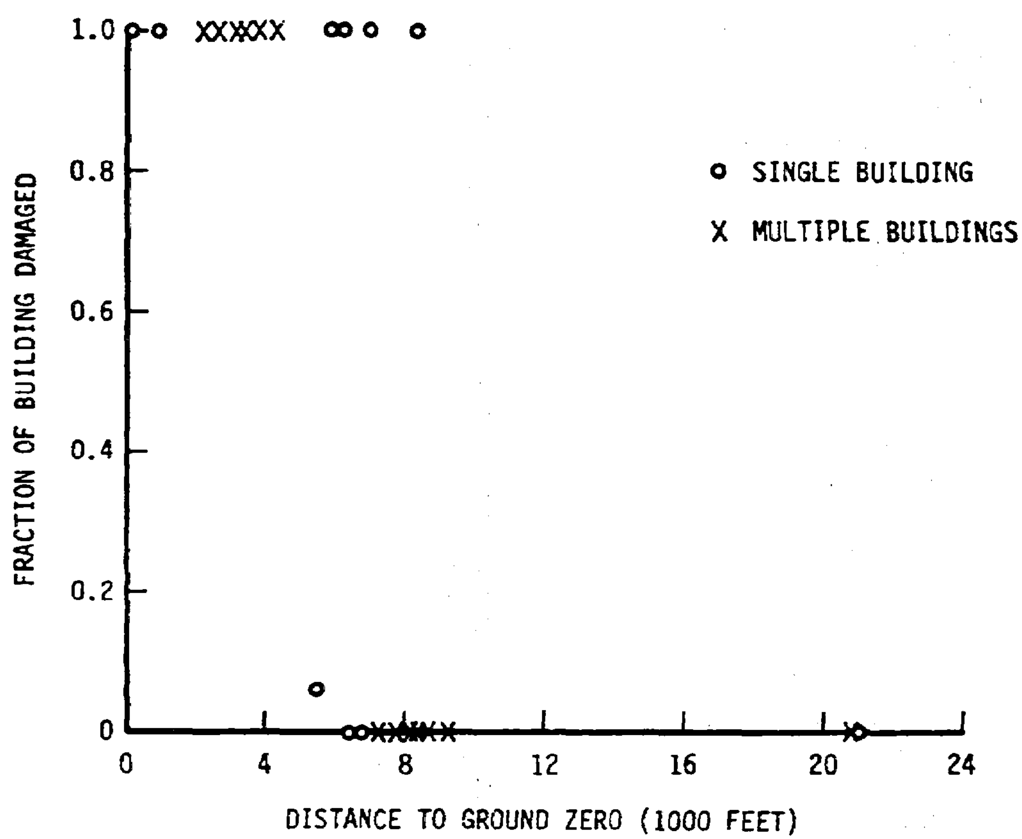


FIGURE 2b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI
STRUCTURAL DAMAGE TO WALLS

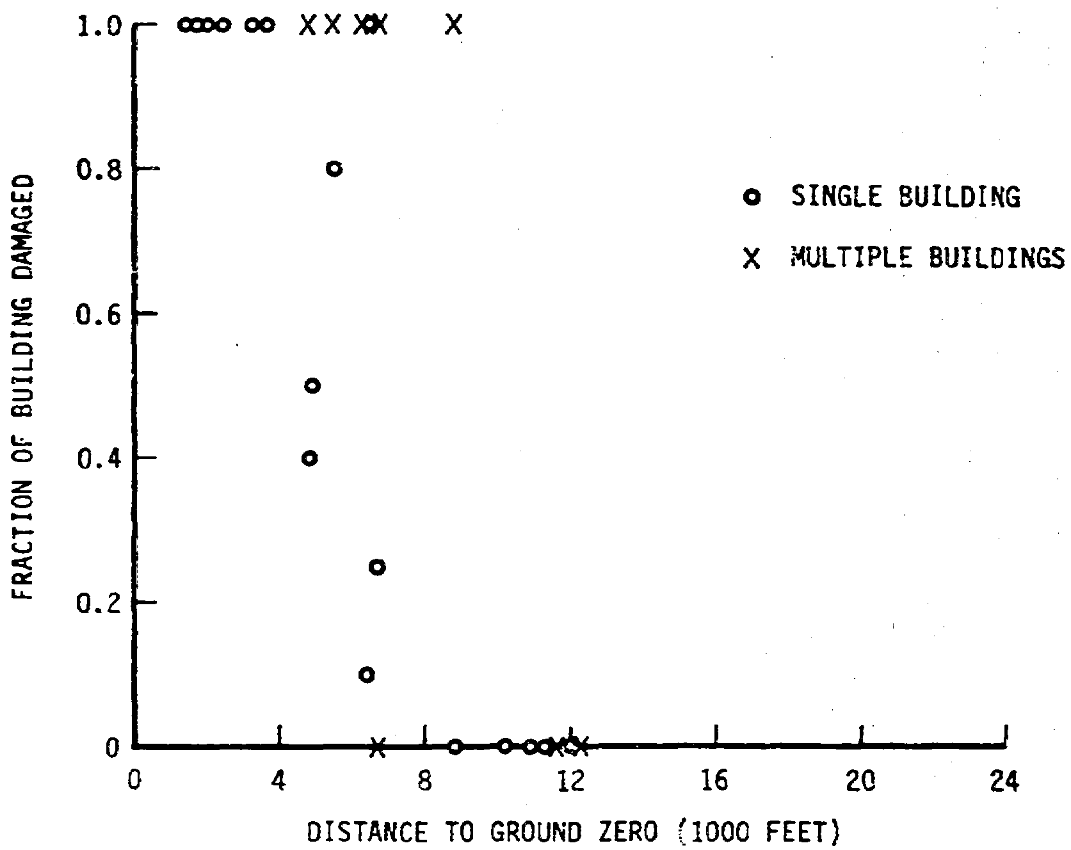


FIGURE 2c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND B_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

STRUCTURAL DAMAGE TO WALLS

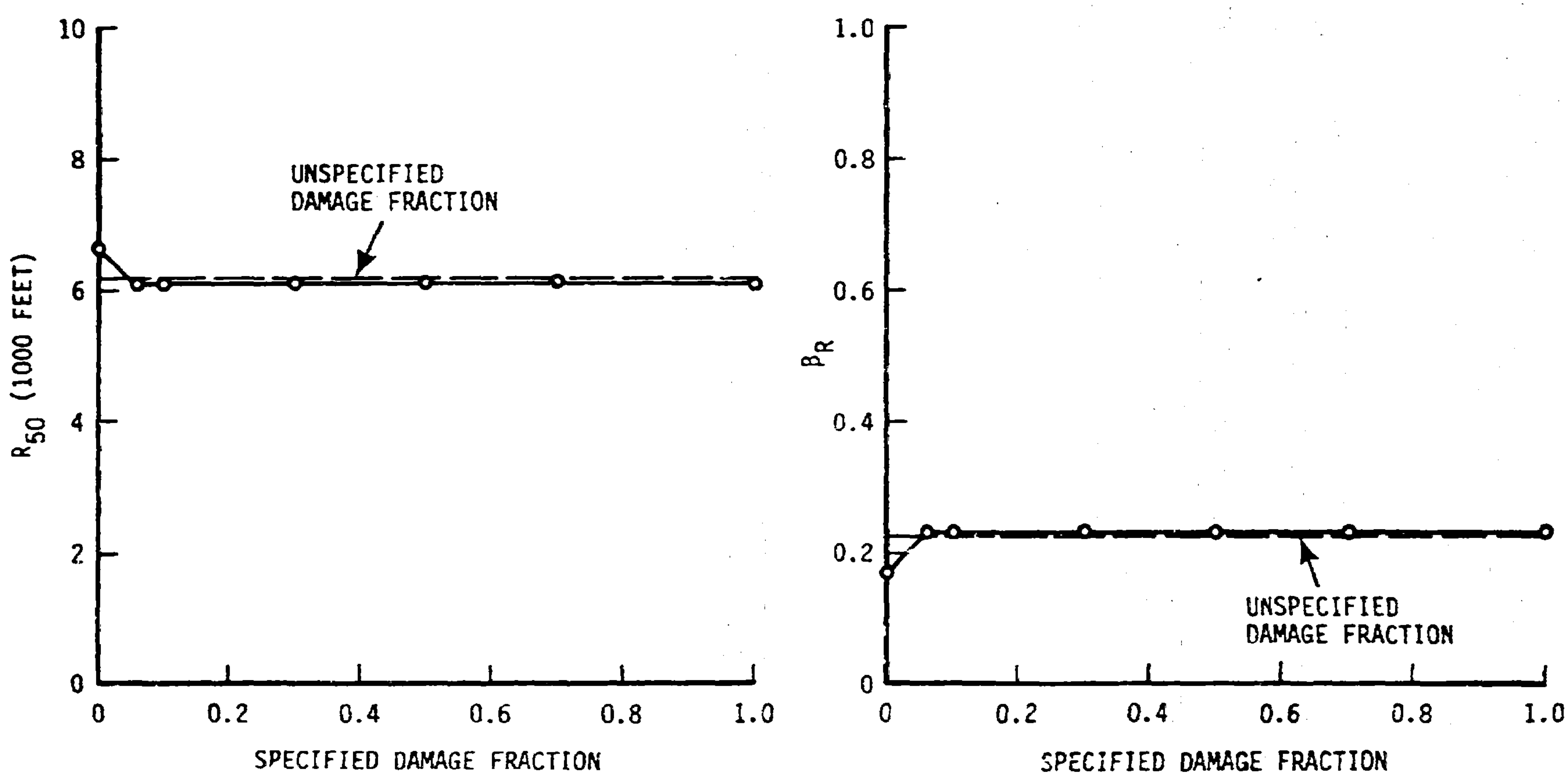


FIGURE 2d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE TO WALLS

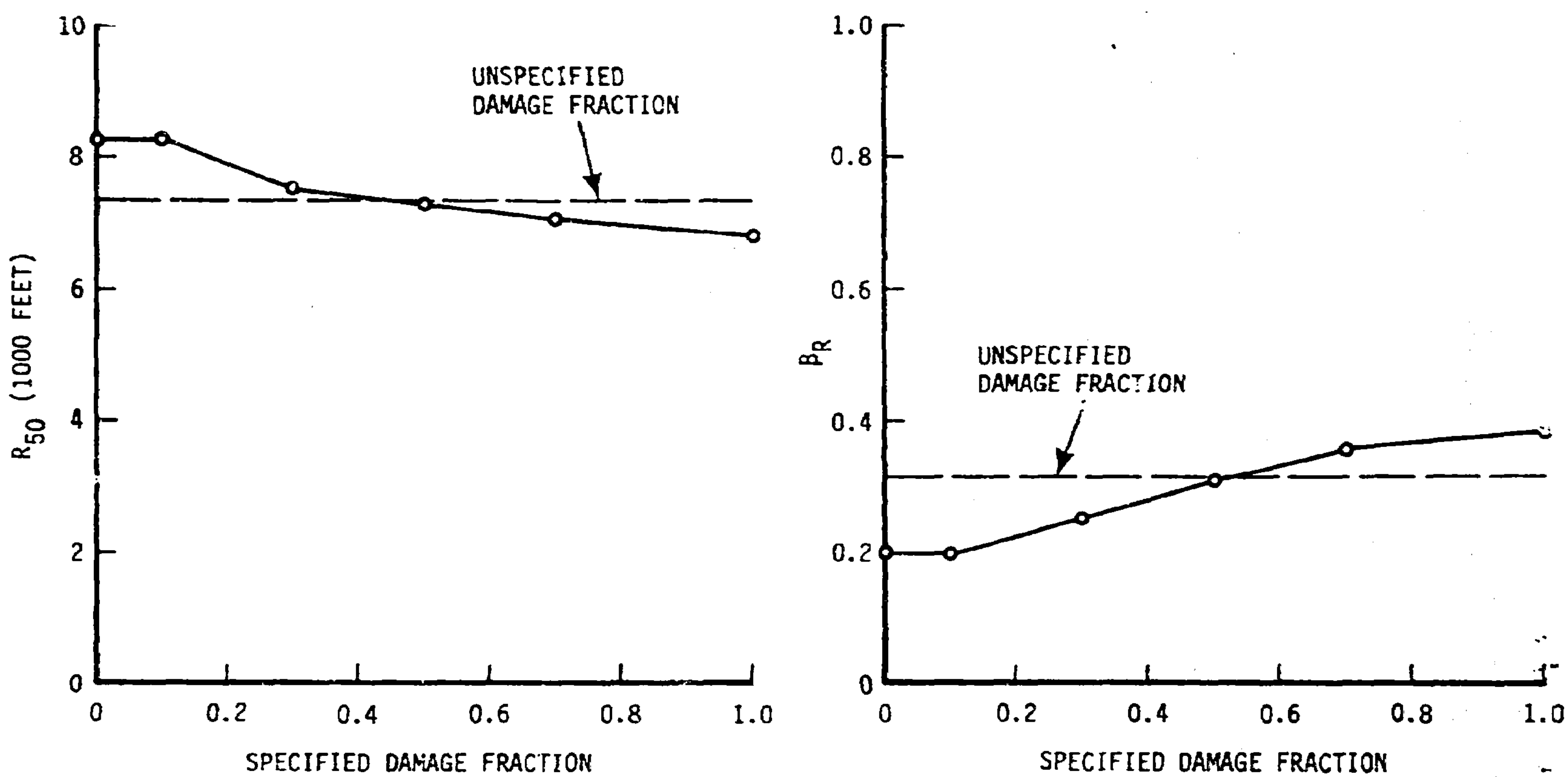


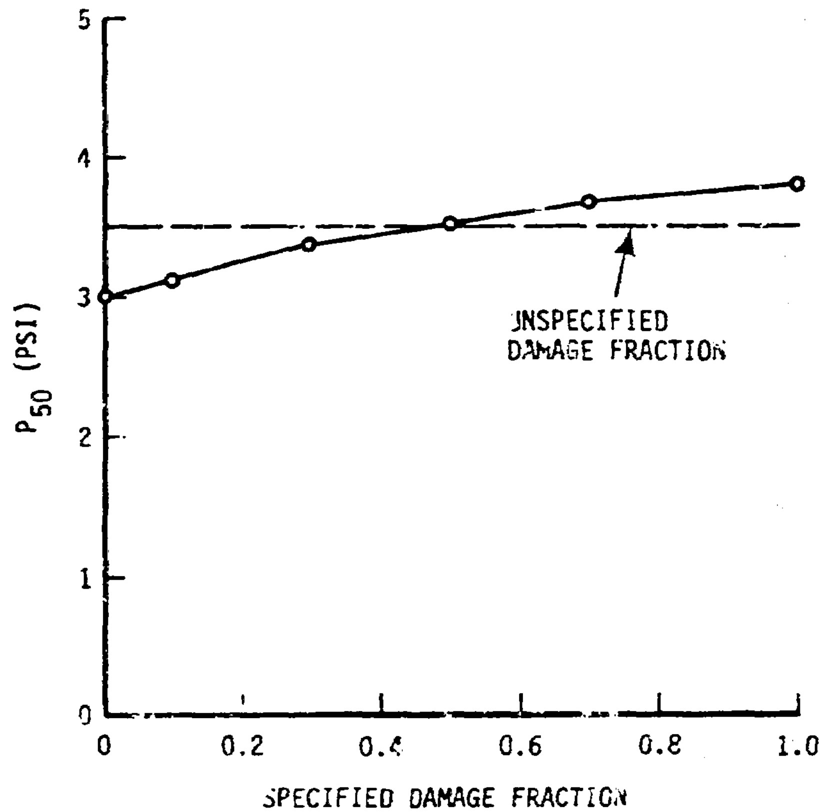
FIGURE 2e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

STRUCTURAL DAMAGE TO WALLS

HIROSHIMA YIELD ASSUMED = 12 KT



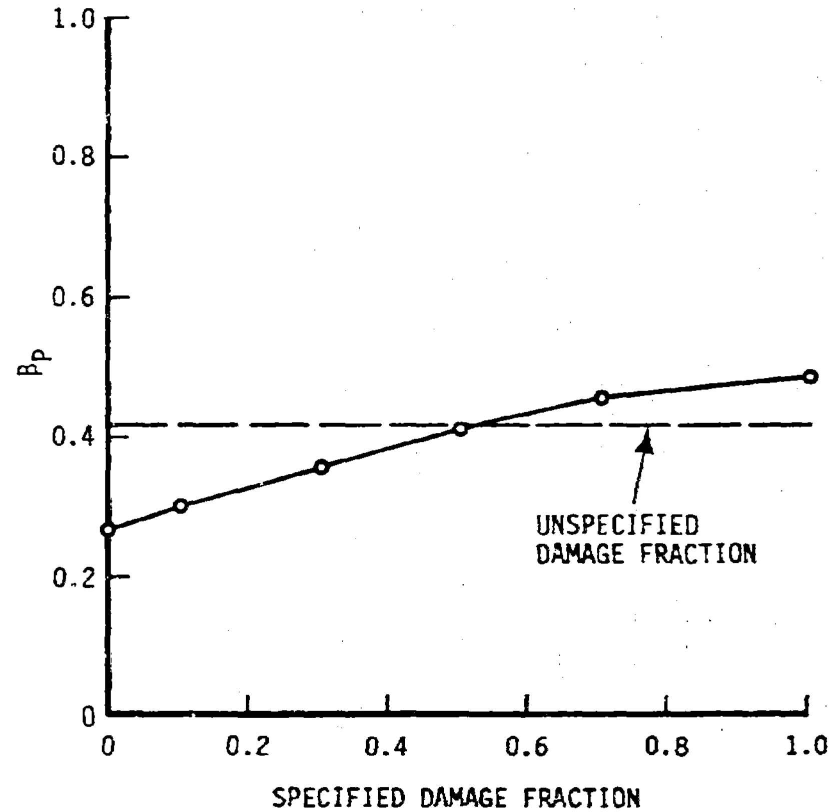


FIGURE 2f

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

STRUCTURAL DAMAGE TO WALLS

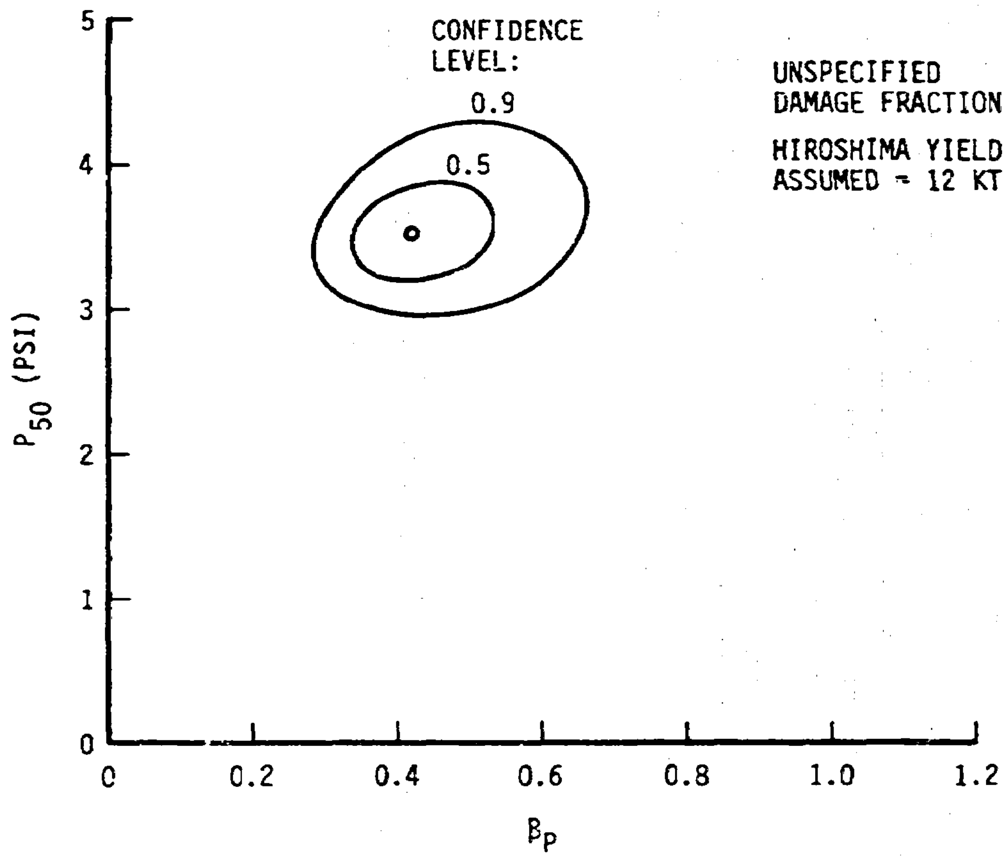


FIGURE 2g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
STRUCTURAL DAMAGE TO WALLS

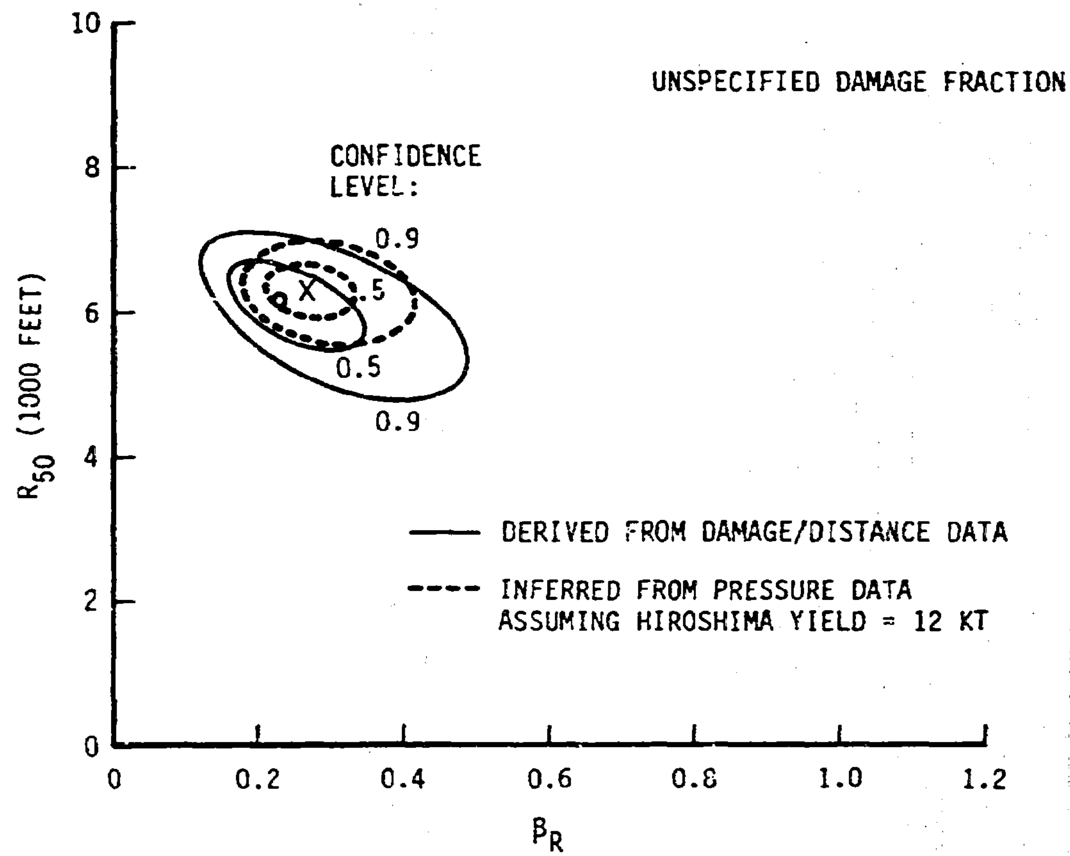


FIGURE 2h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE TO WALLS

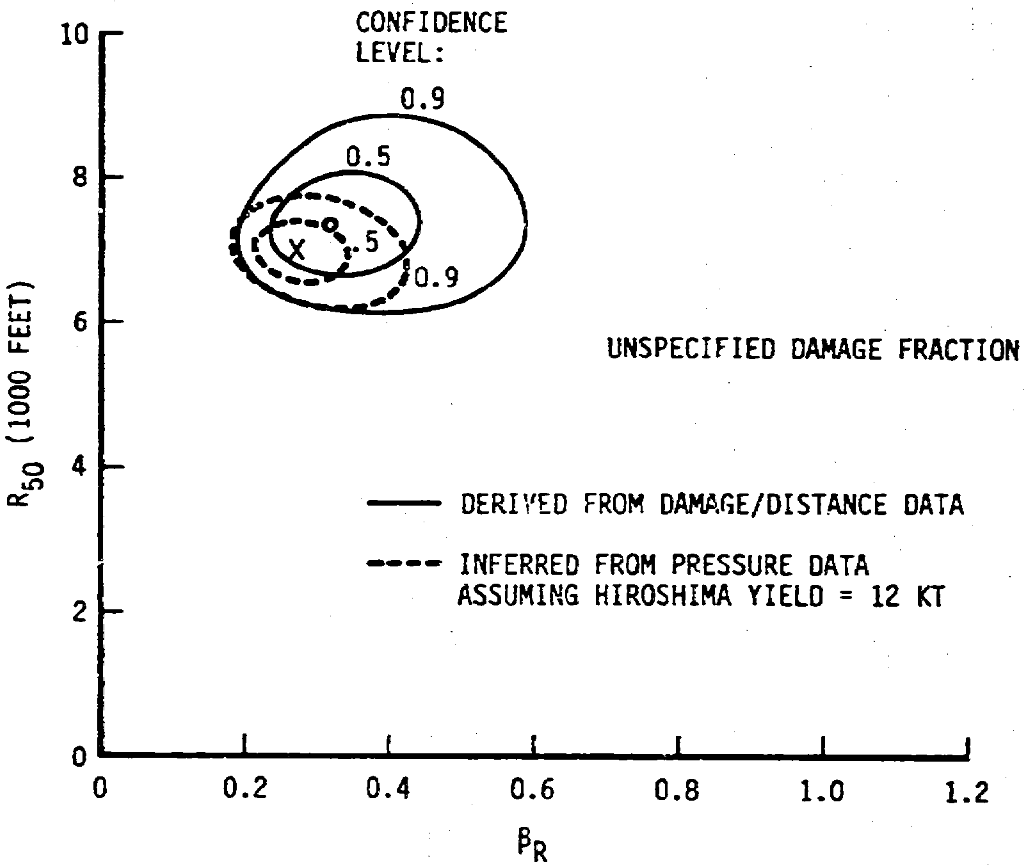


FIGURE 3a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
STEEL ROOF TRUSSES
STRUCTURAL DAMAGE TO ROOFS

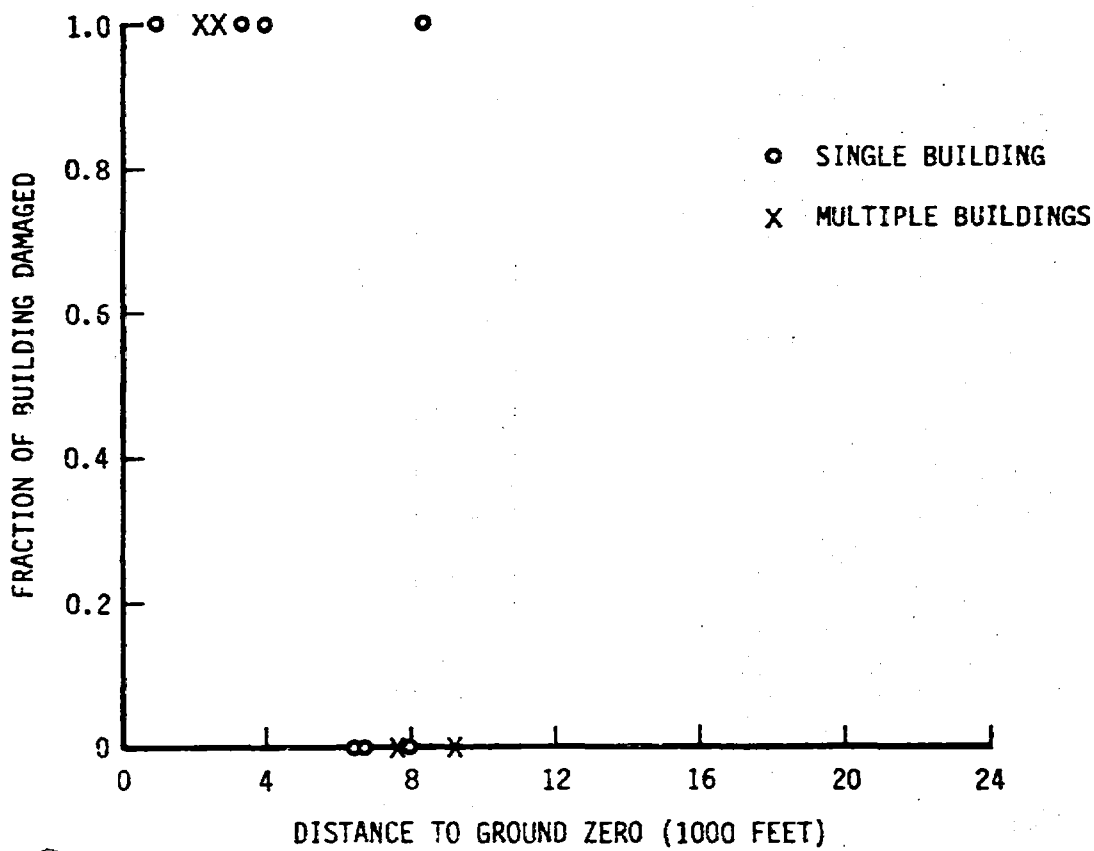


FIGURE 3b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI
STEEL ROOF TRUSSES
STRUCTURAL DAMAGE TO ROOFS

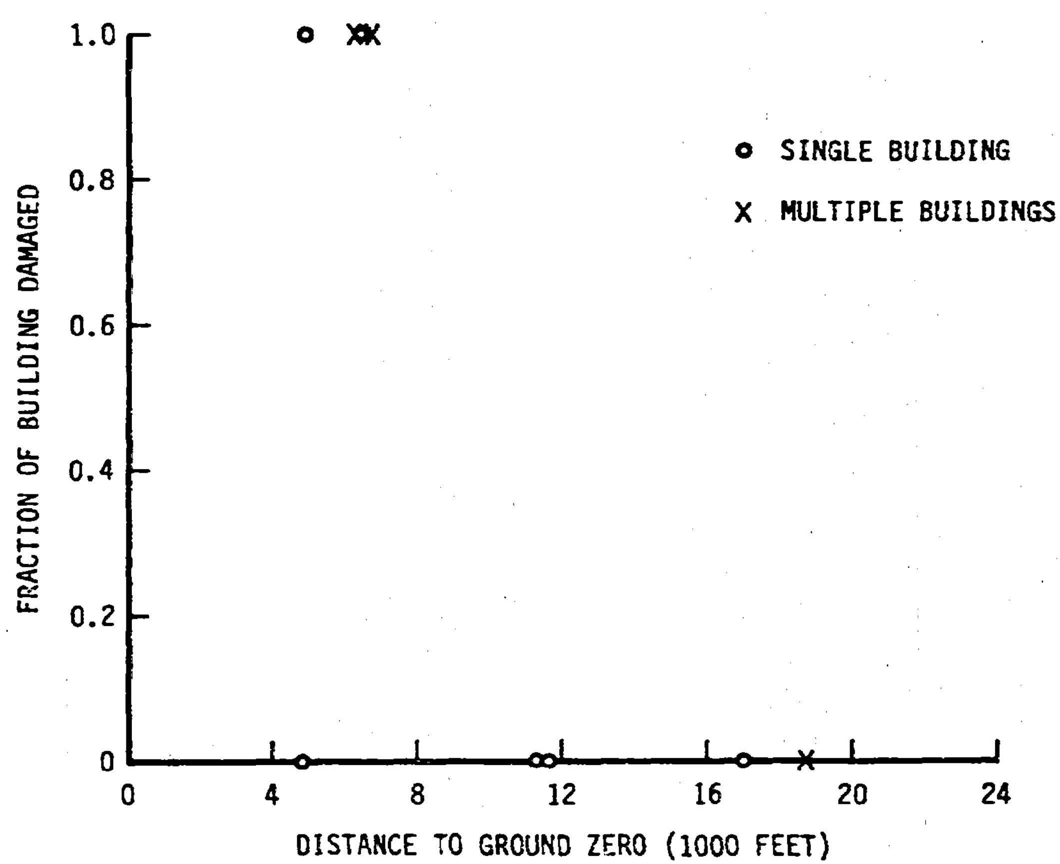


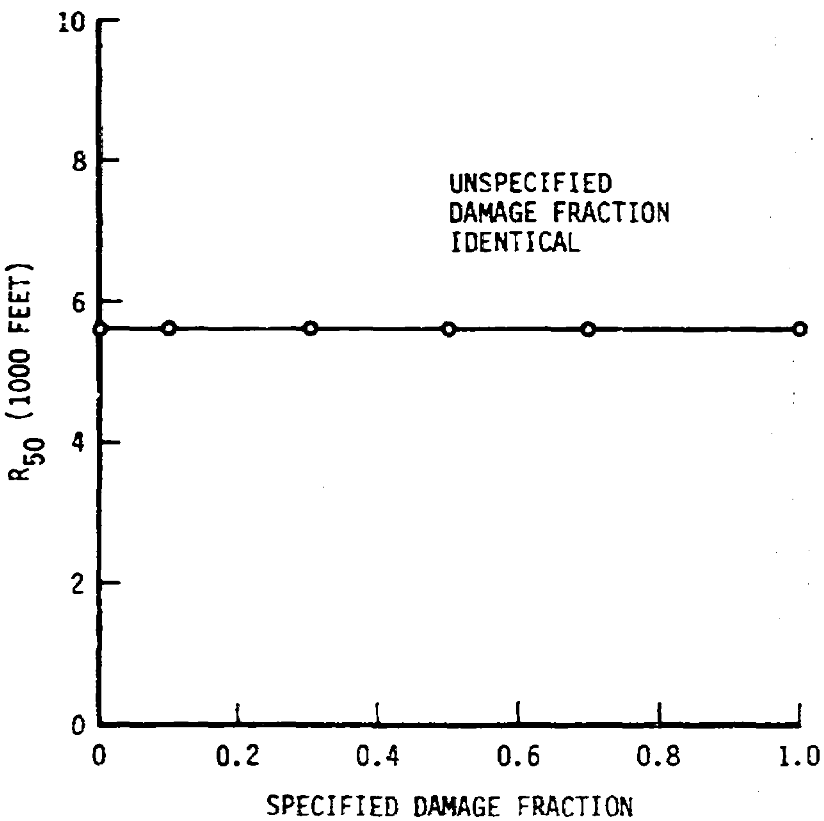
FIGURE 3c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS



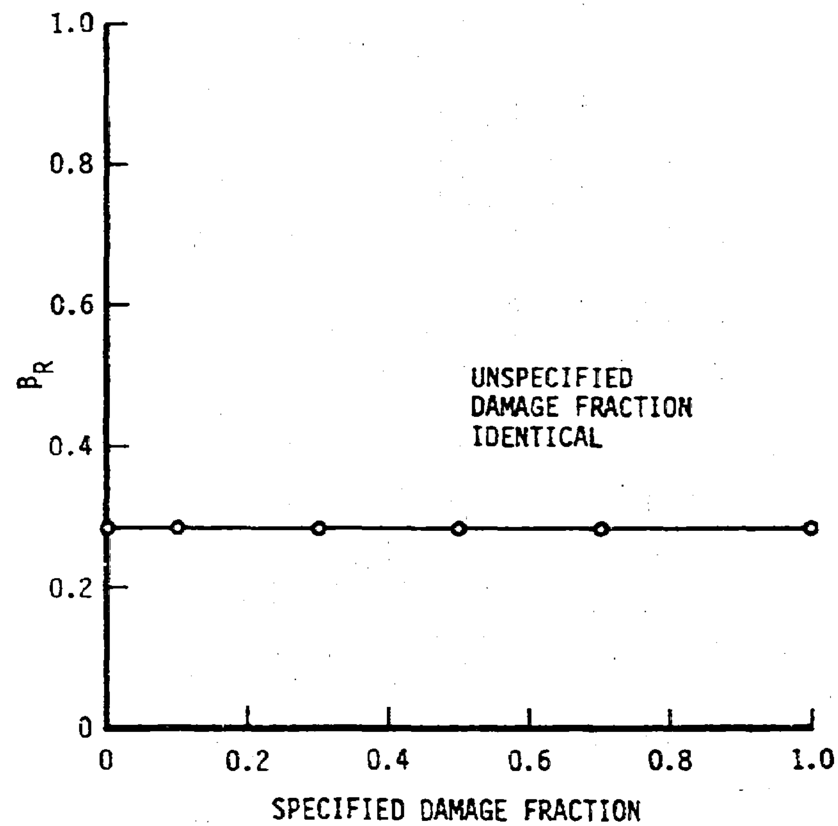


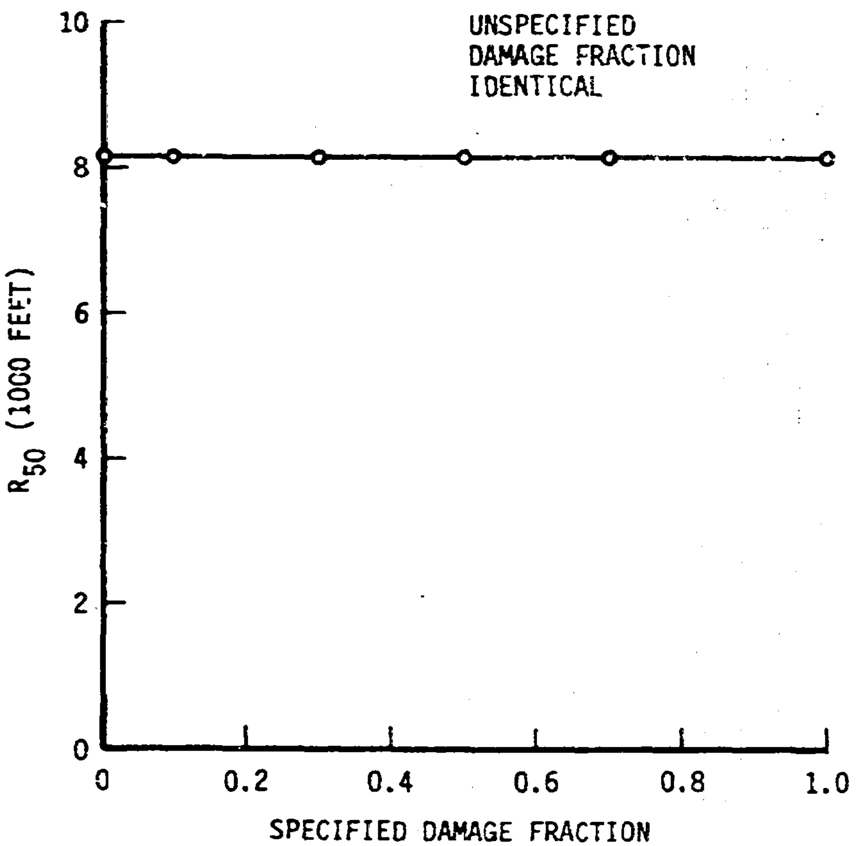
FIGURE 3d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS



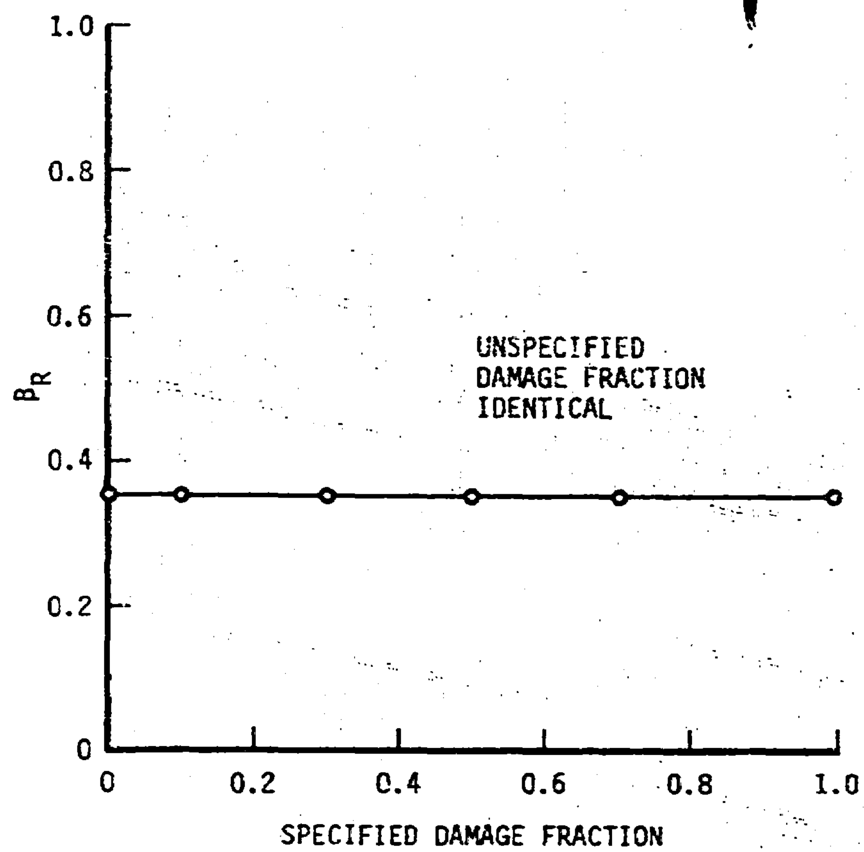


FIGURE 3e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

HIROSHIMA YIELD ASSUMED = 12 KT

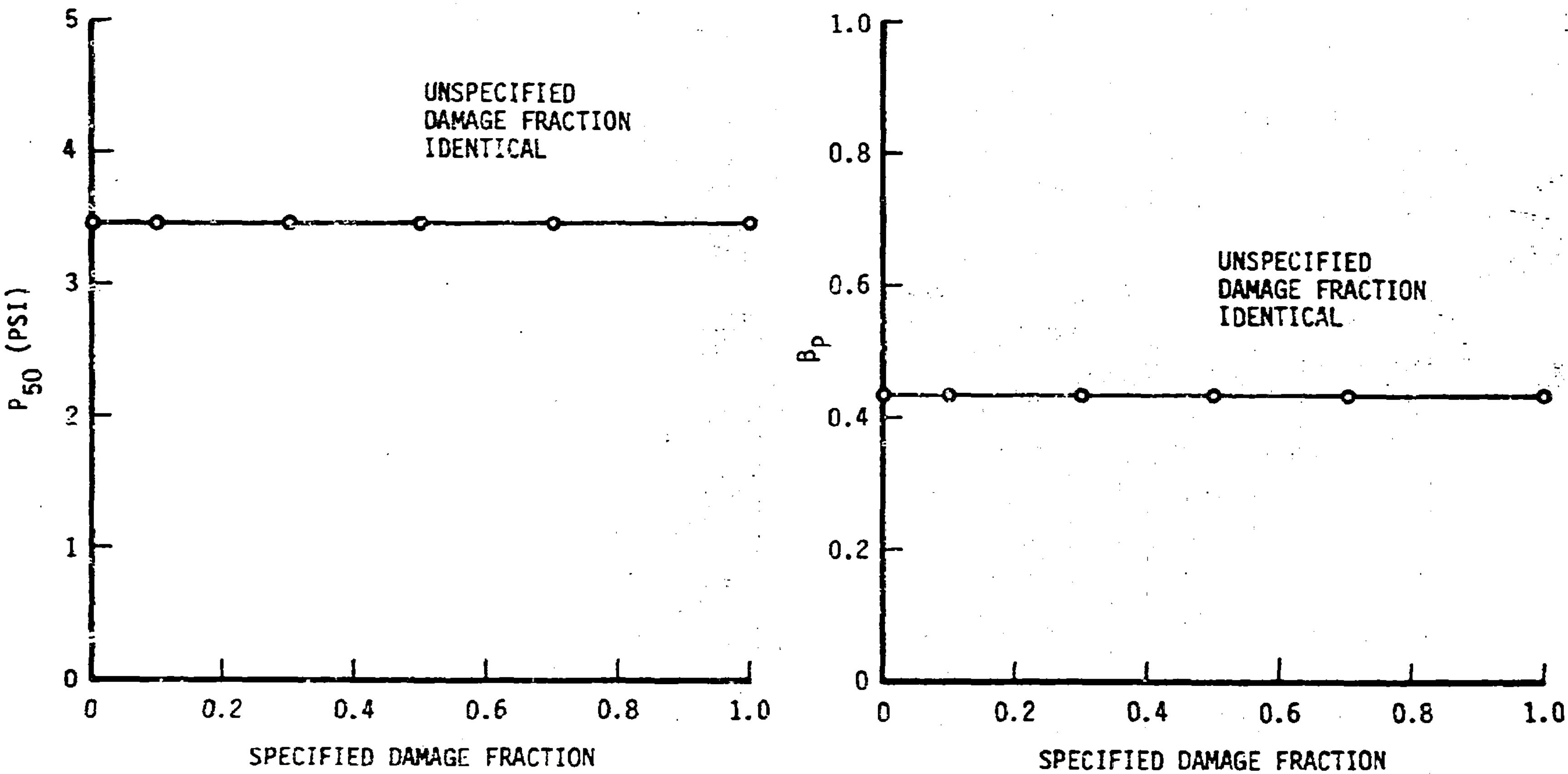


FIGURE 3f

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

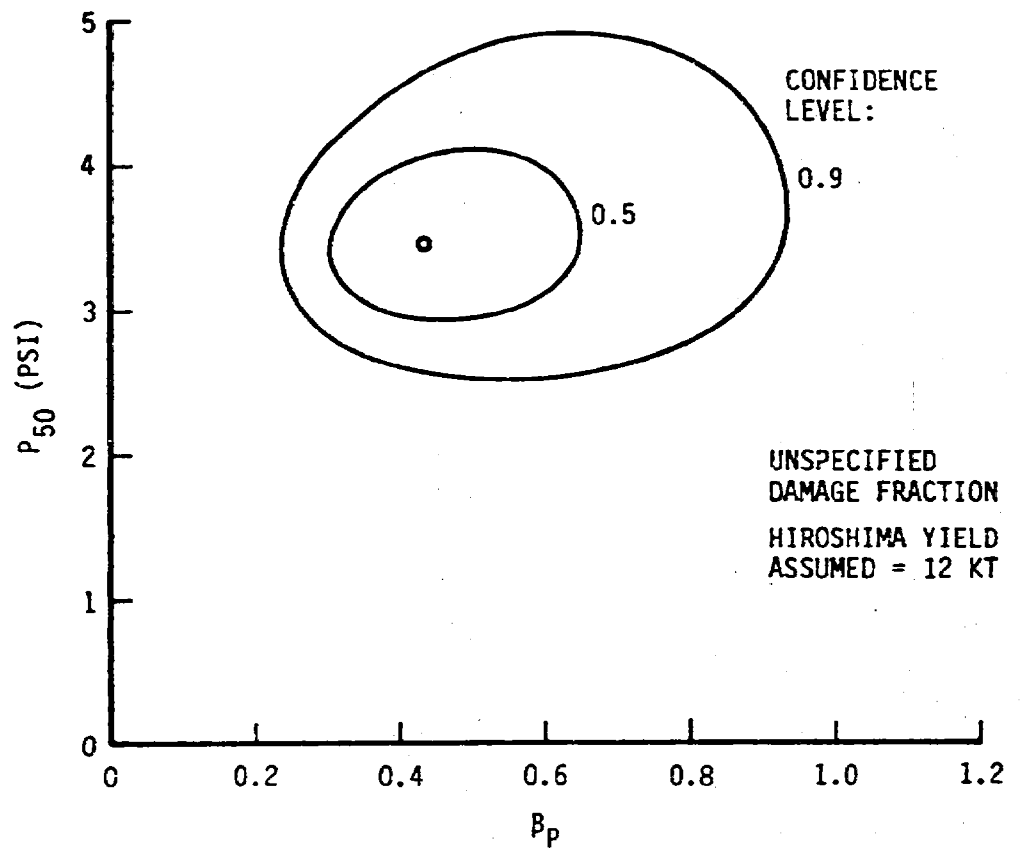


FIGURE 3g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

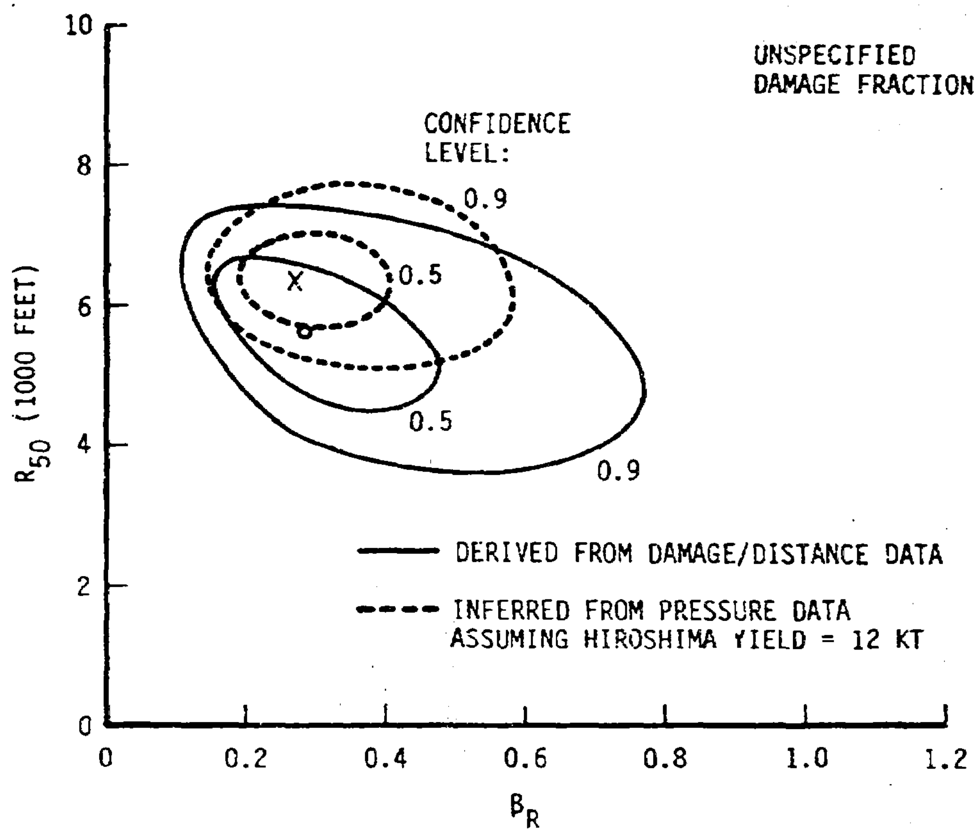


FIGURE 3h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

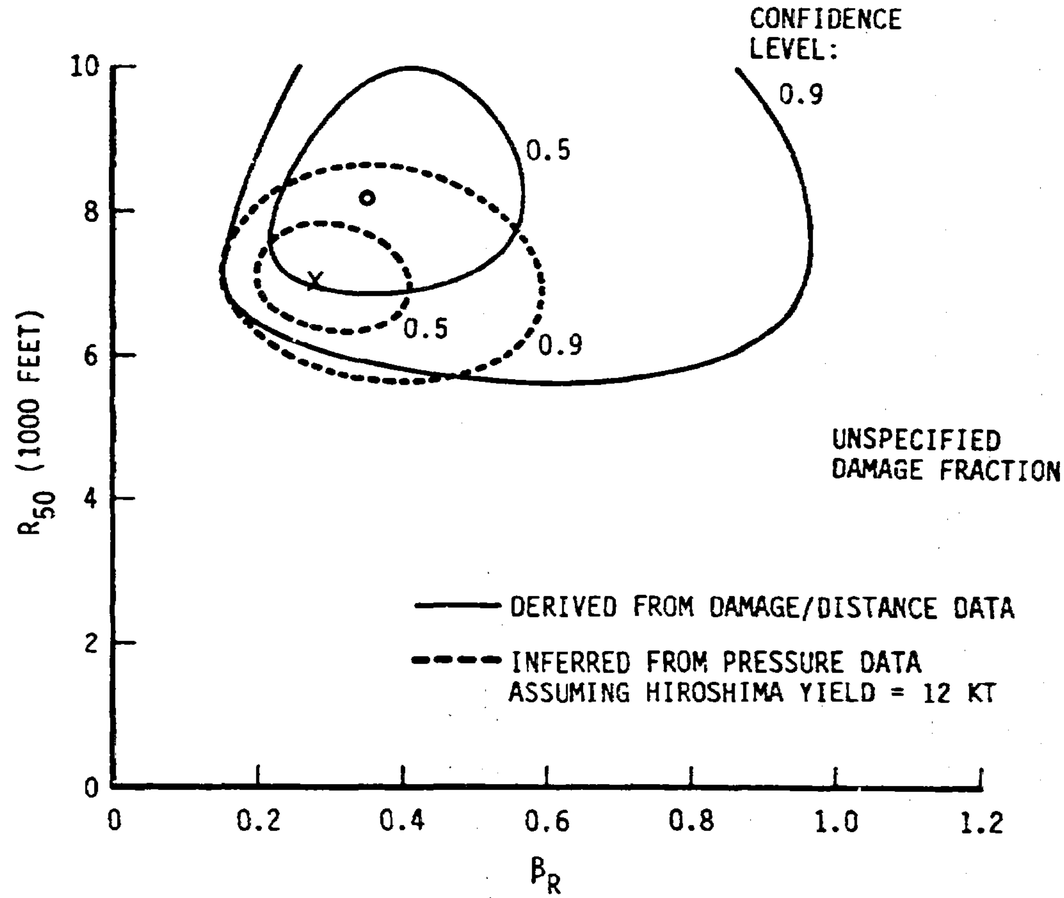


FIGURE 4a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
WOOD ROOF TRUSSES
STRUCTURAL DAMAGE TO ROOFS

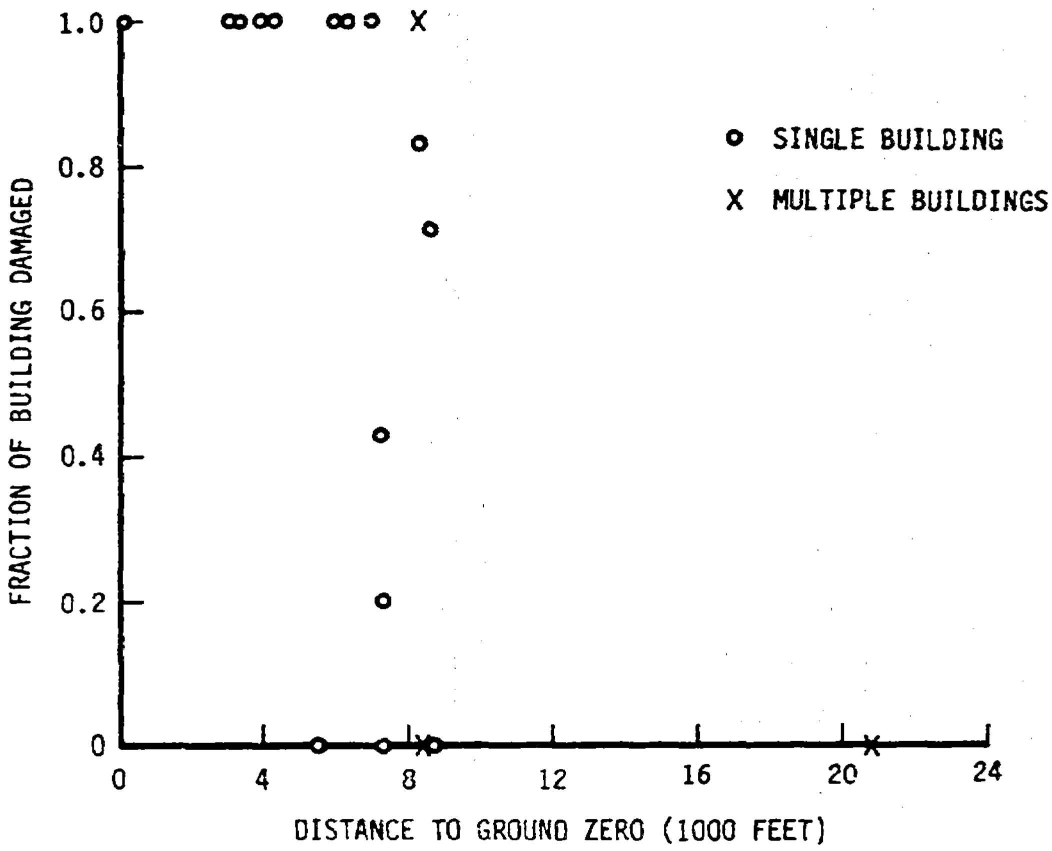


FIGURE 4b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI
WOOD ROOF TRUSSES
STRUCTURAL DAMAGE TO ROOFS

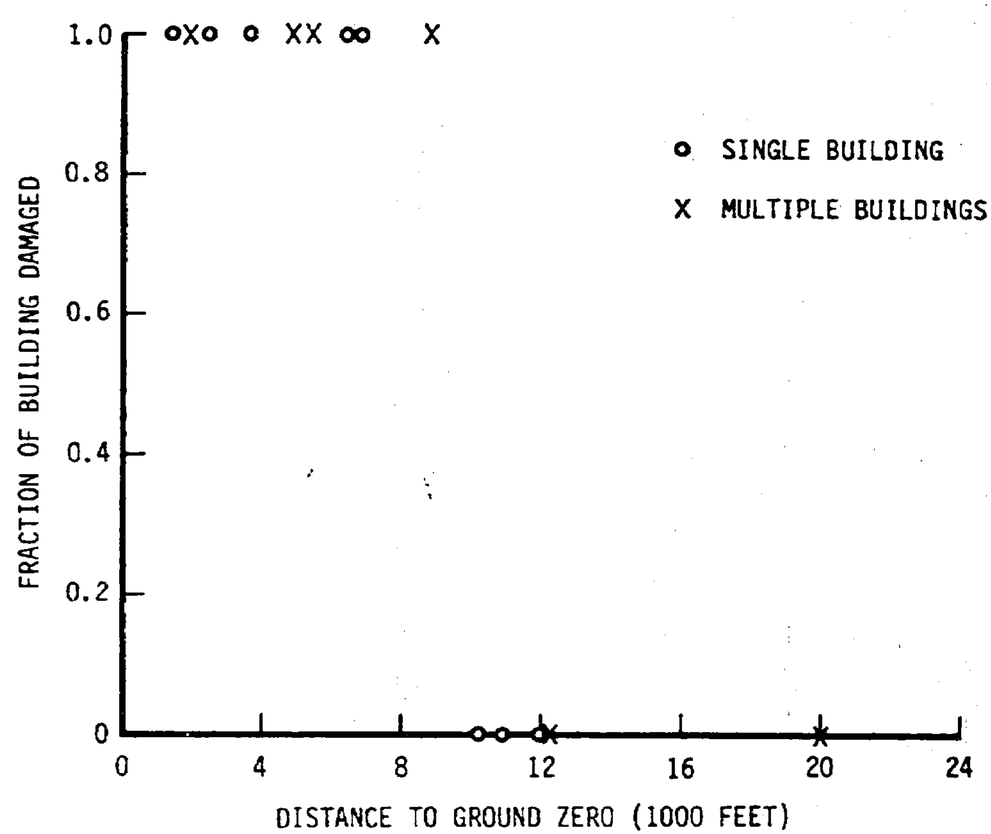


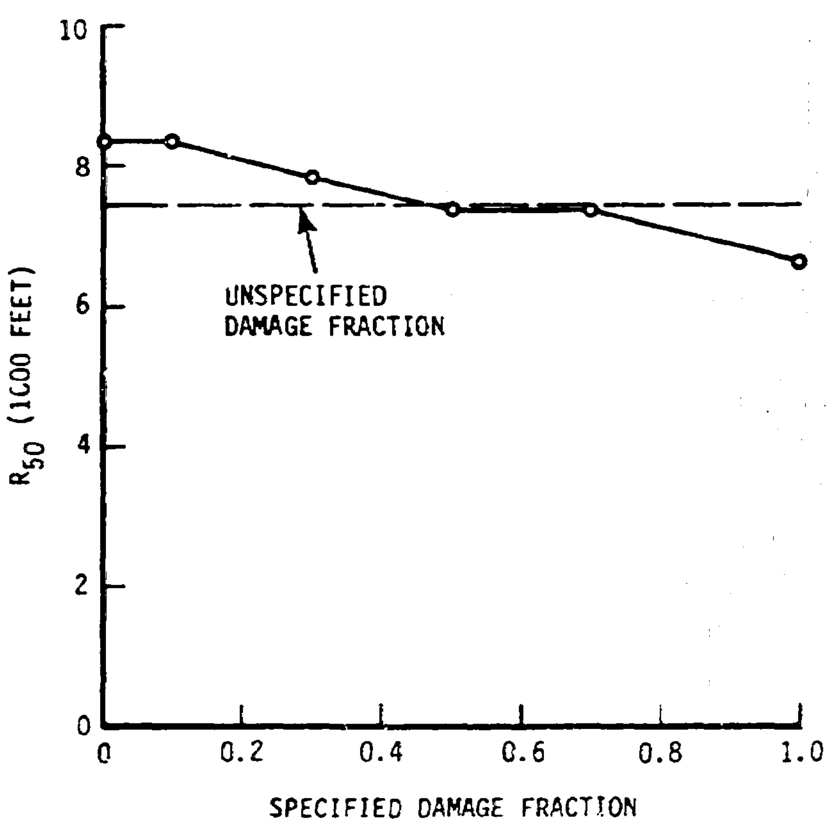
FIGURE 4c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

WOOD ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS



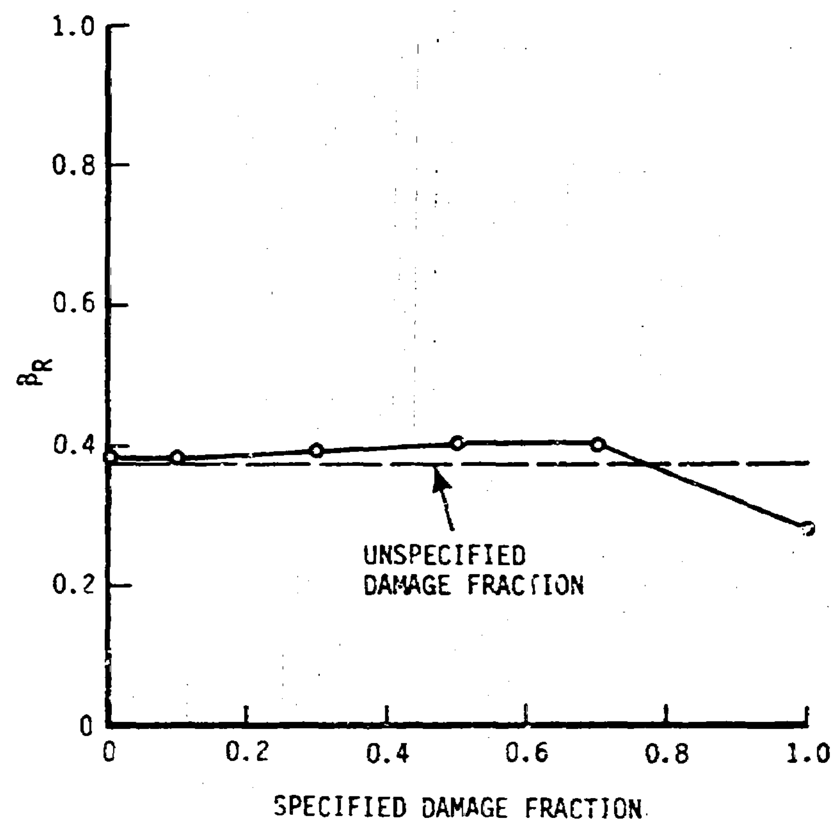


FIGURE 4d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

WOOD ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

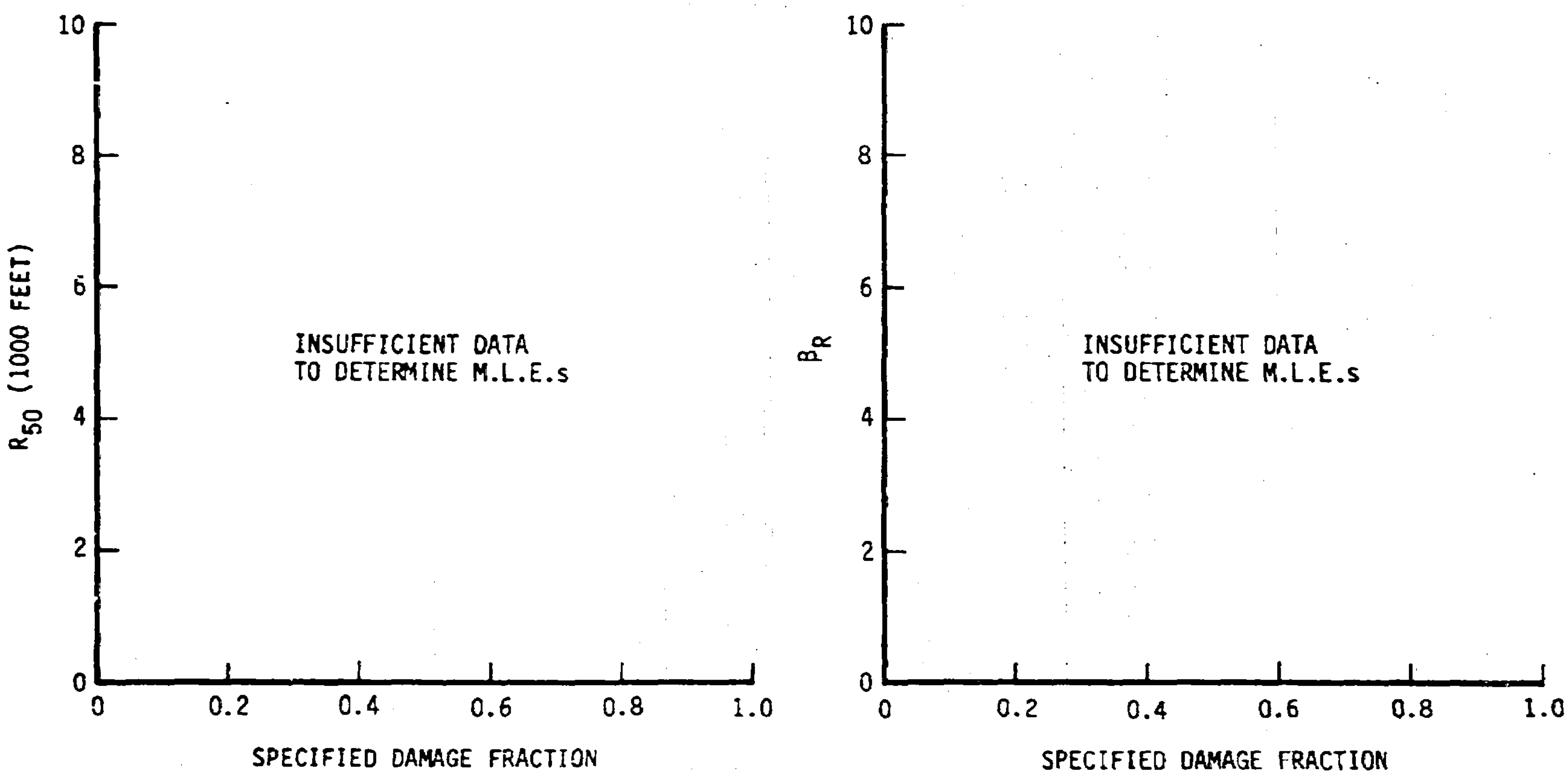


FIGURE 4e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{5C} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

WOOD ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

HIROSHIMA YIELD ASSUMED = 12 KT

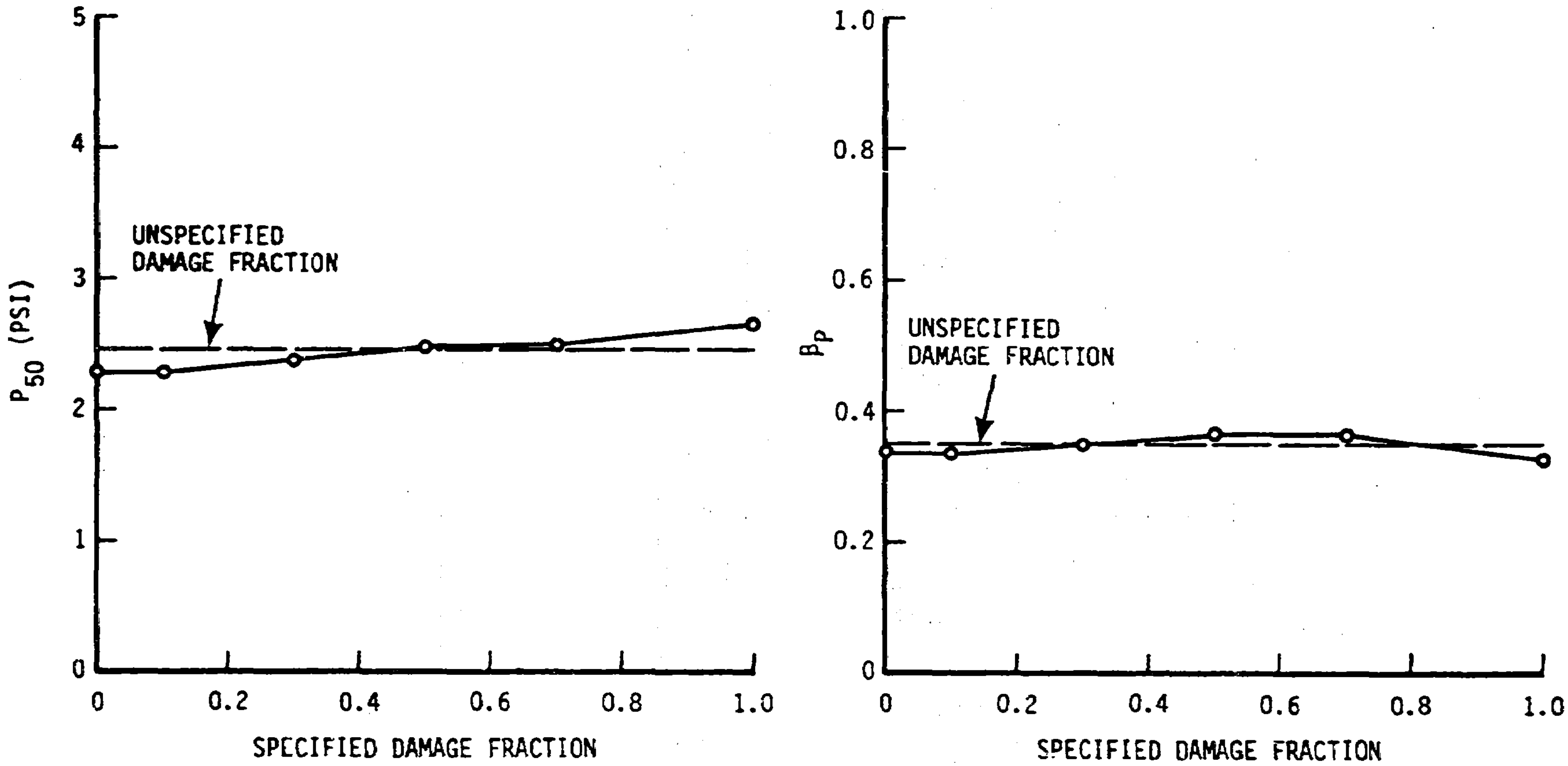


FIGURE 4f

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

WOOD ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

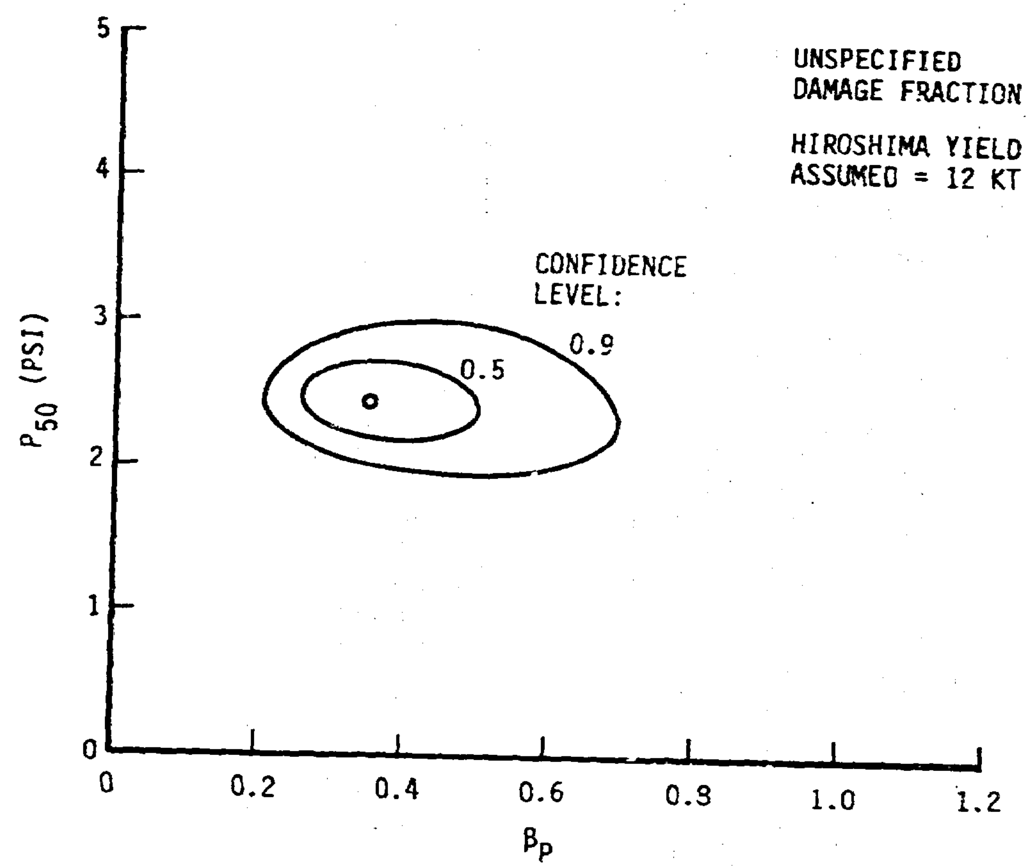


FIGURE 4g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

WOOD ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

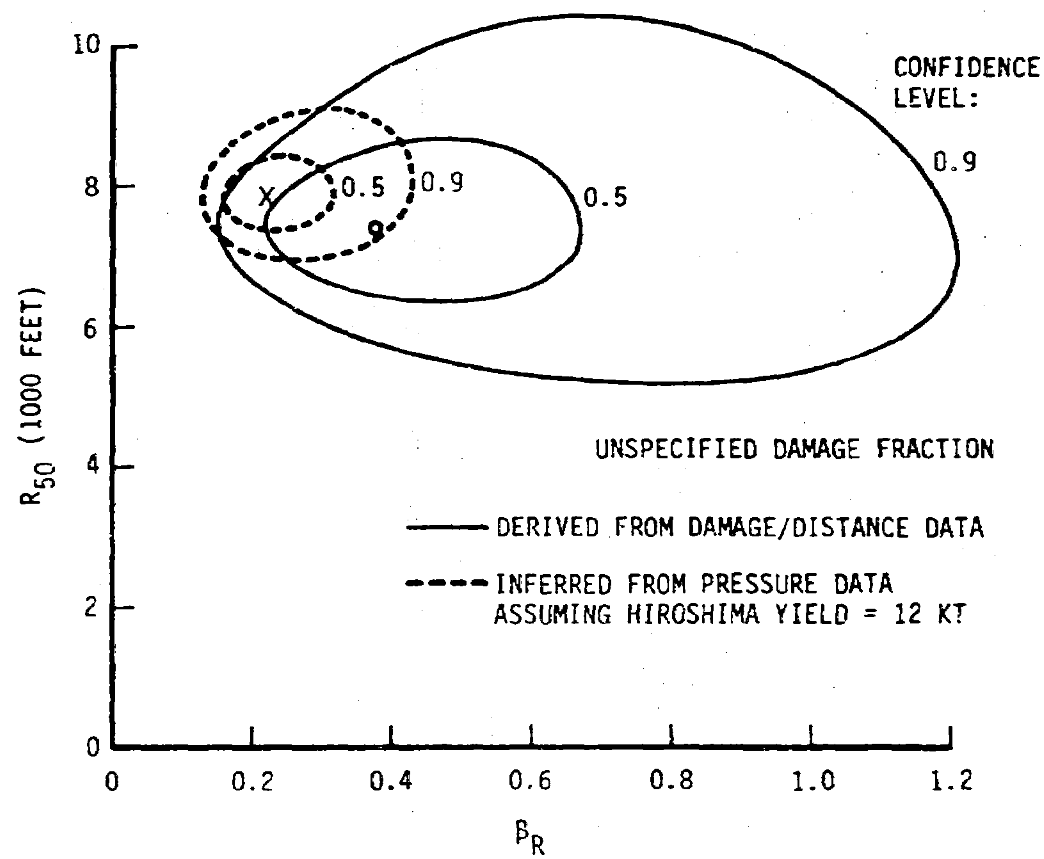


FIGURE 4h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

WOOD ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

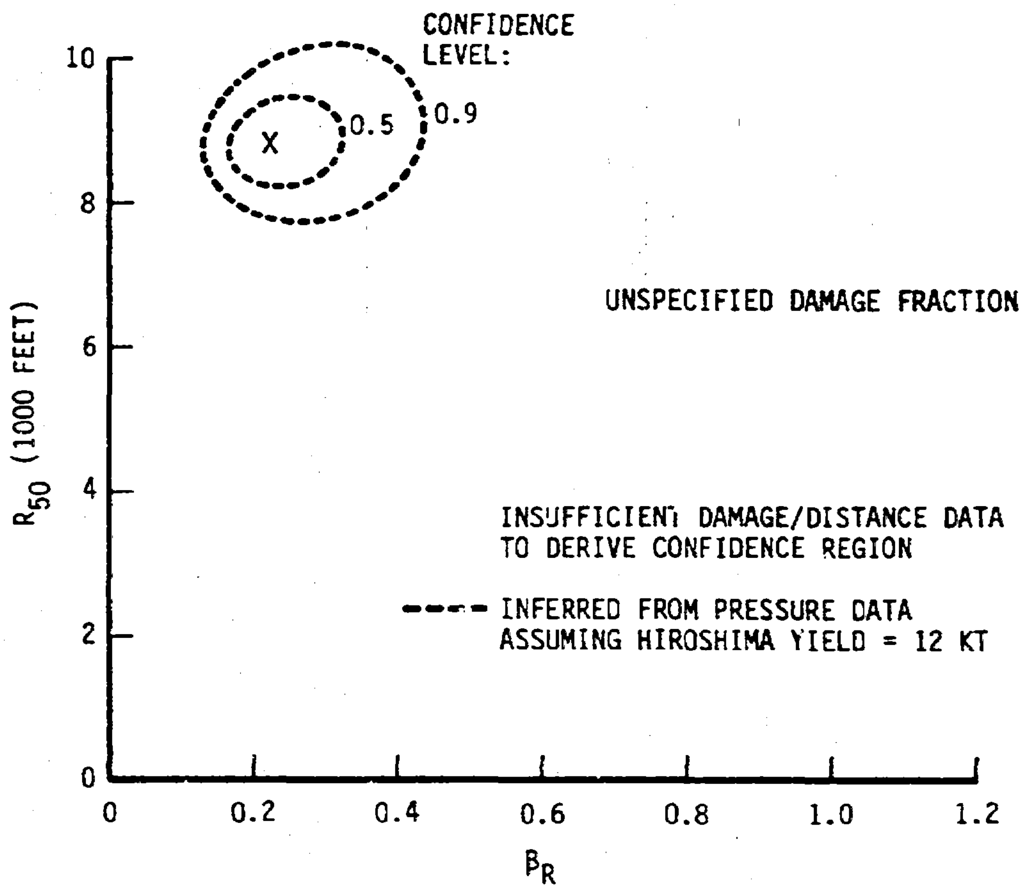


FIGURE 5a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
SUPERFICIAL DAMAGE CRITERIA

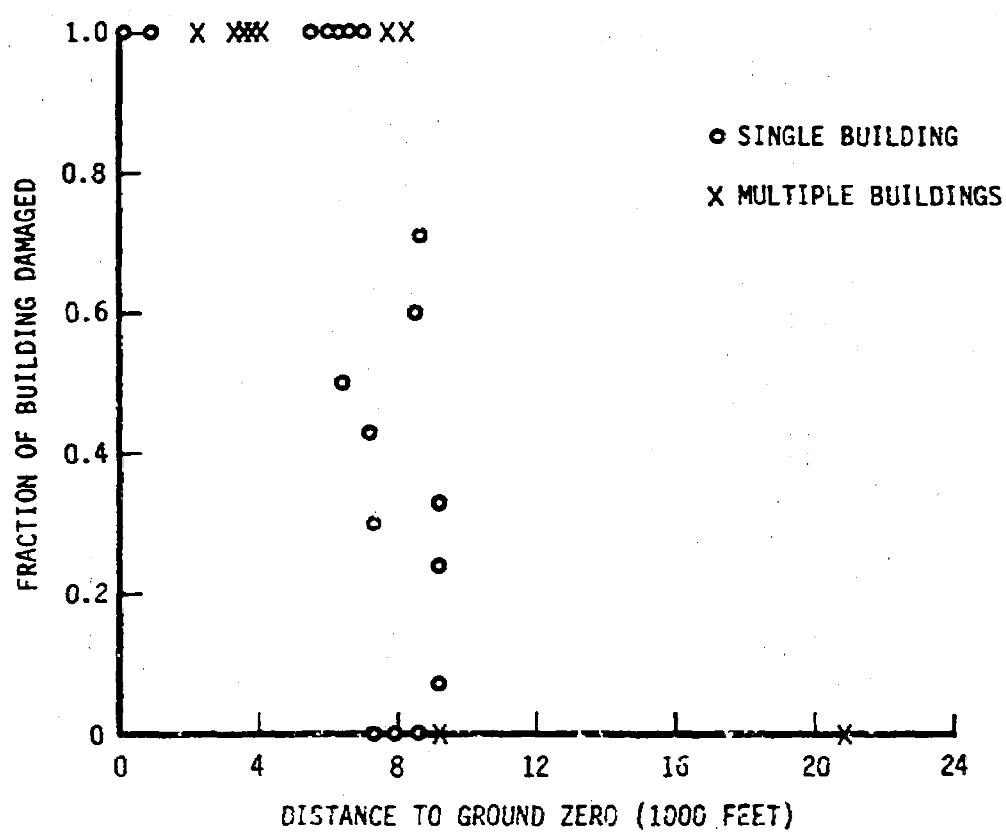


FIGURE 5b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI
SUPERFICIAL DAMAGE CRITERIA

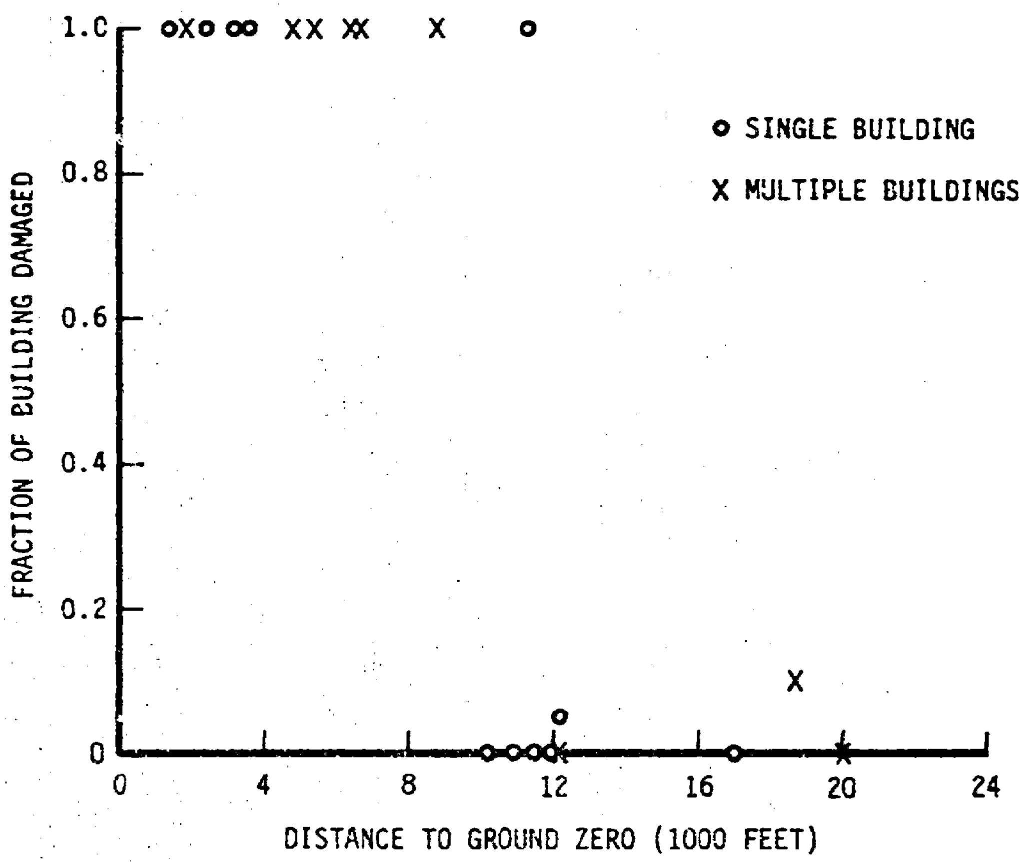


FIGURE 5c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND B_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

SUPERFICIAL DAMAGE CRITERIA

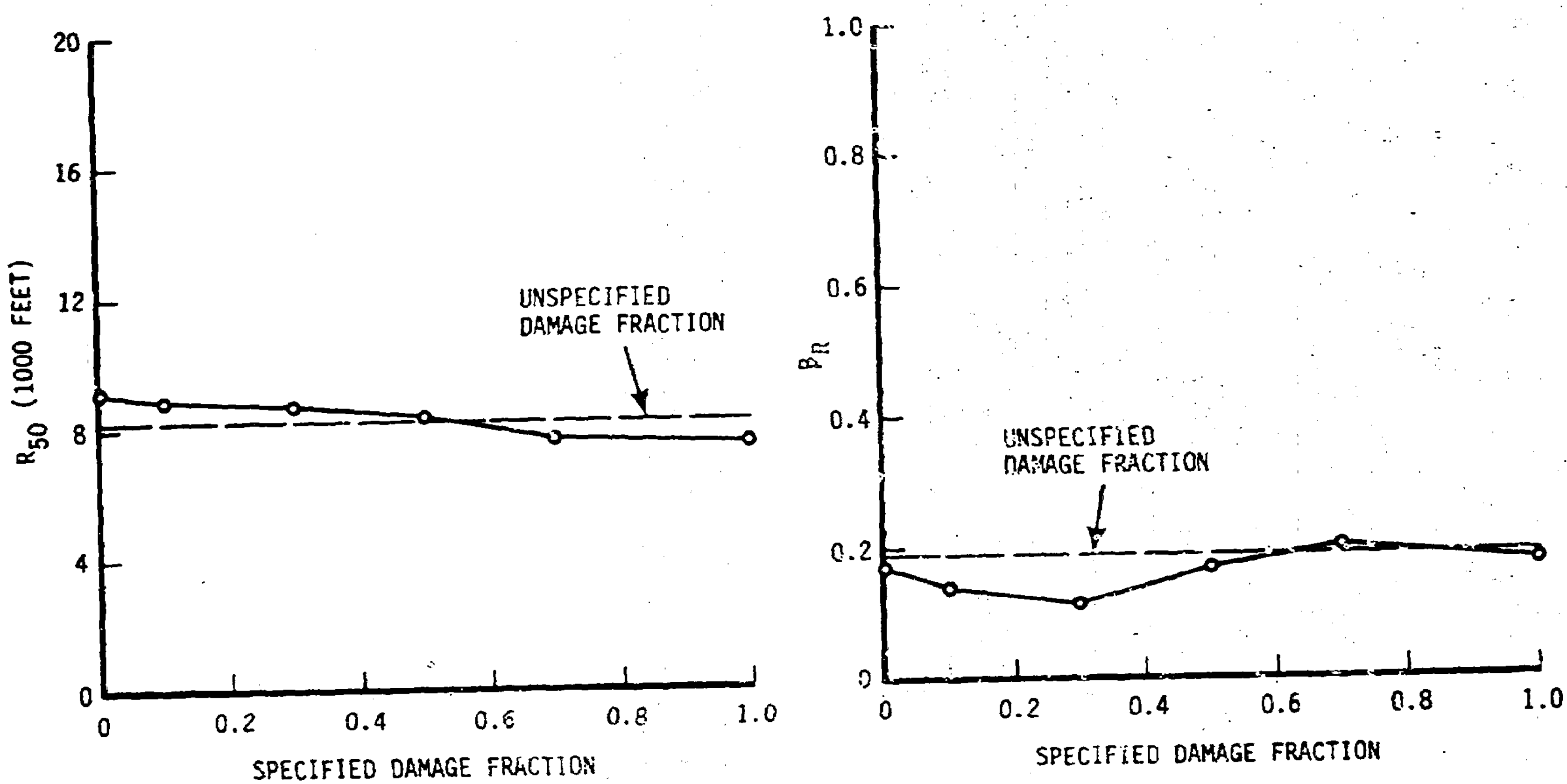
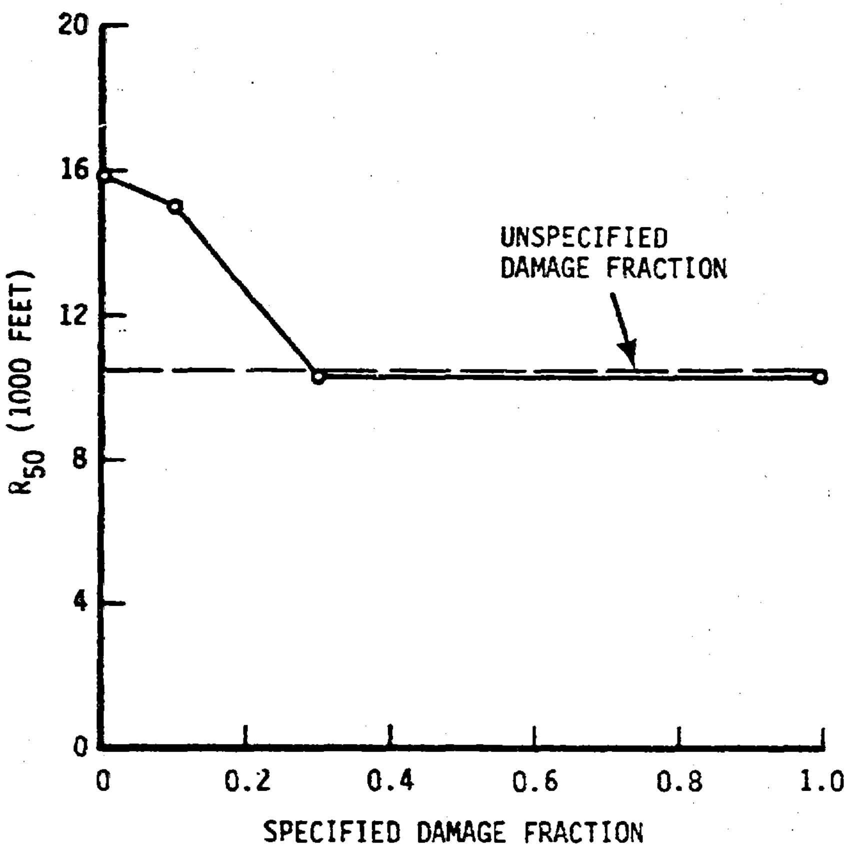


FIGURE 5d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

SUPERFICIAL DAMAGE CRITERIA



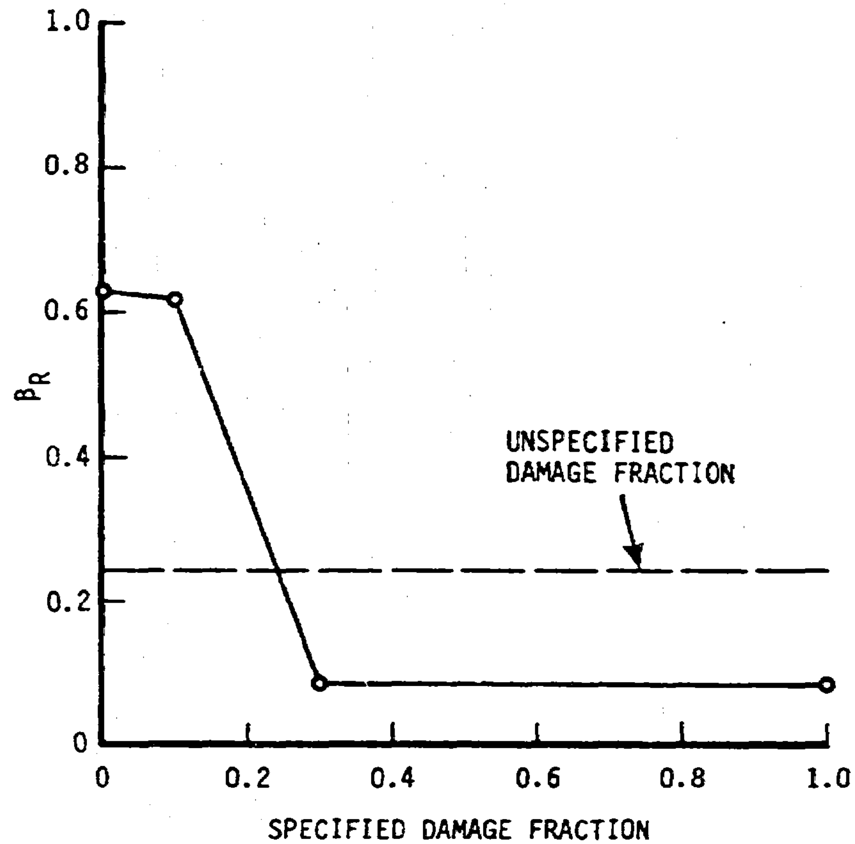


FIGURE 5e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS
SUPERFICIAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT

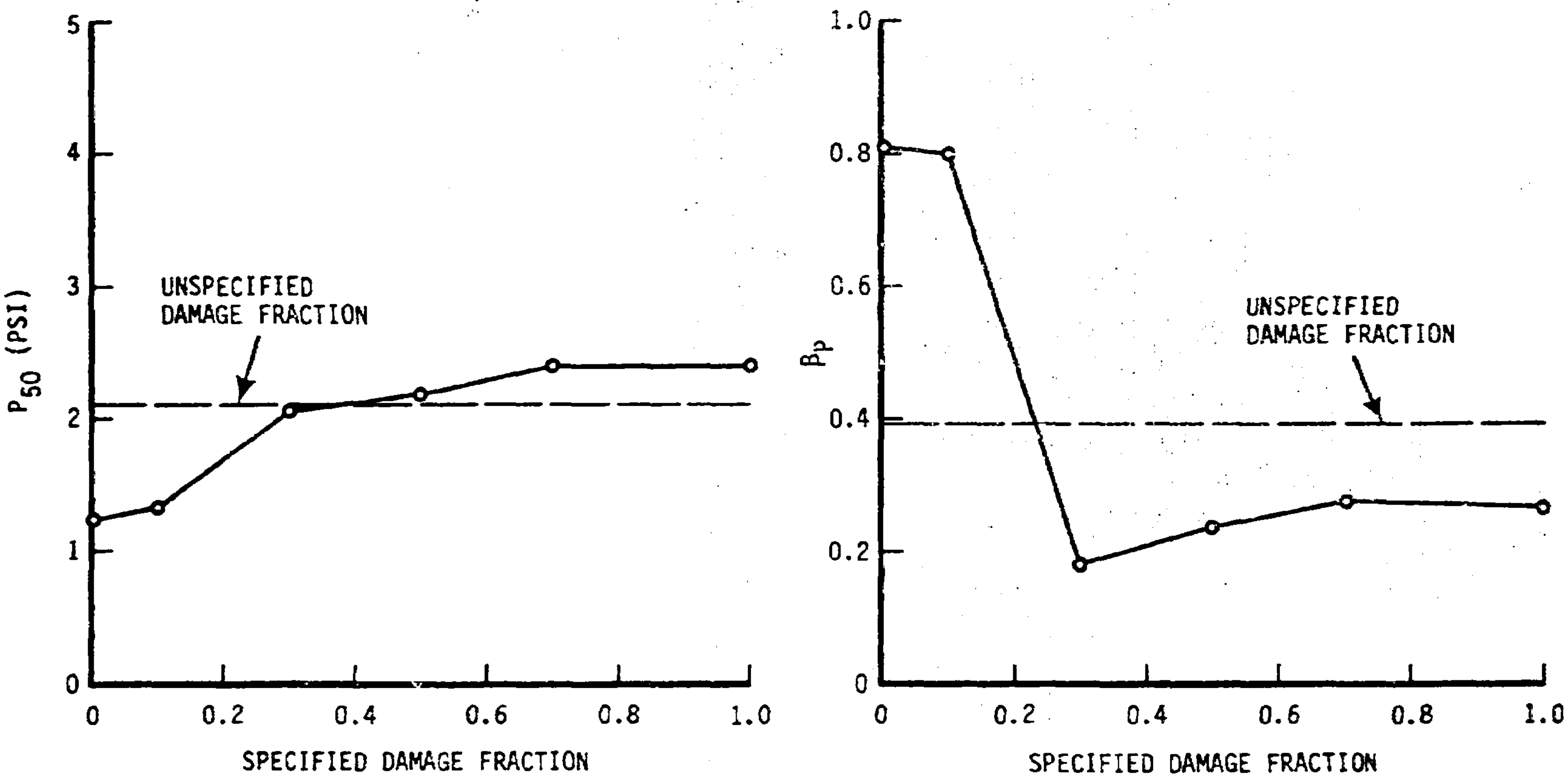


FIGURE 5f

CONFIDENCE REGIONS FOR P_{50} AND β_p

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

SUPERFICIAL DAMAGE CRITERIA

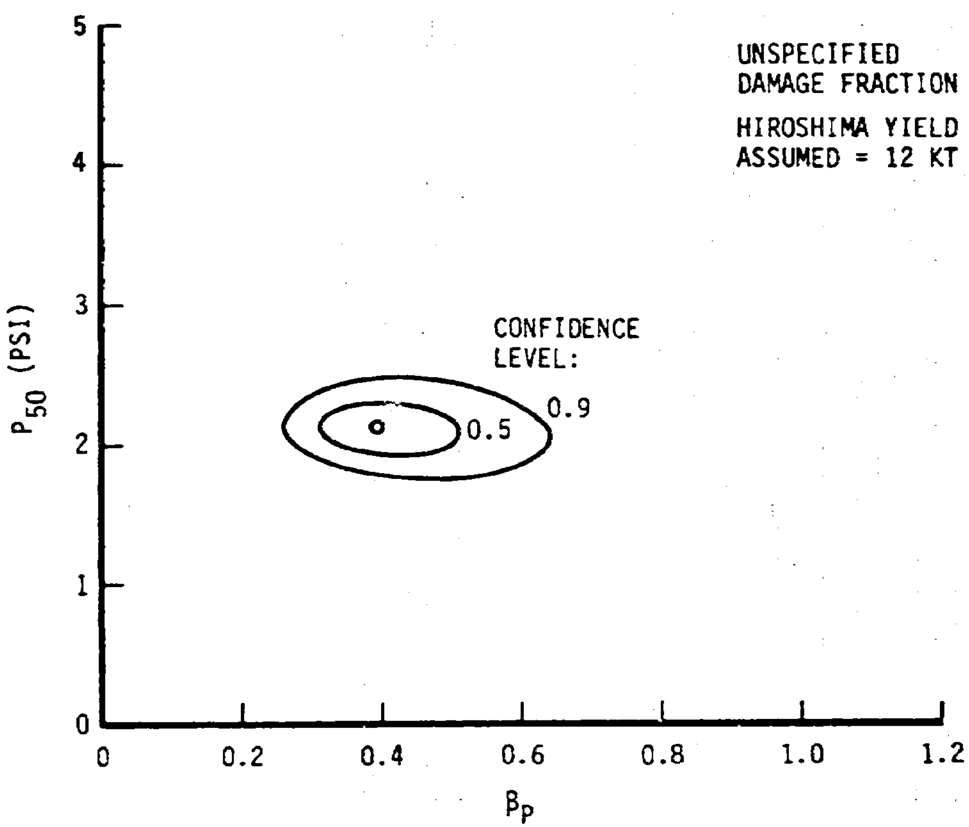


FIGURE 5g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

SUPERFICIAL DAMAGE CRITERIA

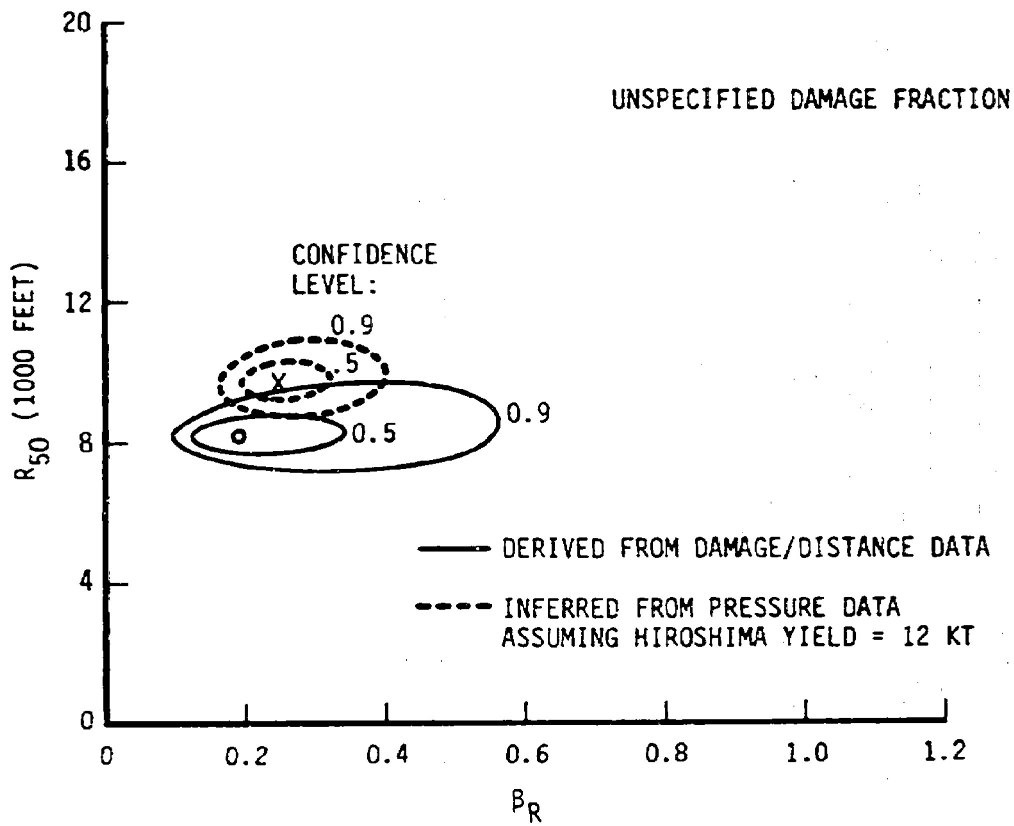


FIGURE 5h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI
SUPERFICIAL DAMAGE CRITERIA

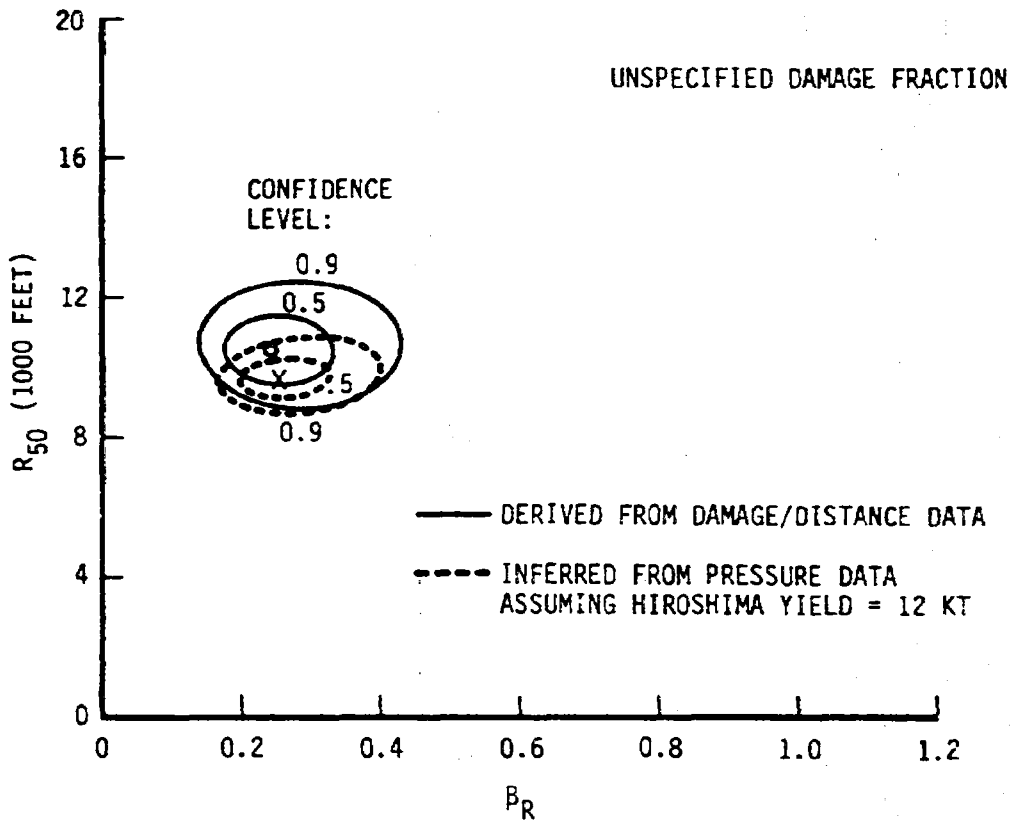


FIGURE 6a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
ROOF COVER MATERIAL FAILS SLOWLY
SUPERFICIAL DAMAGE CRITERIA

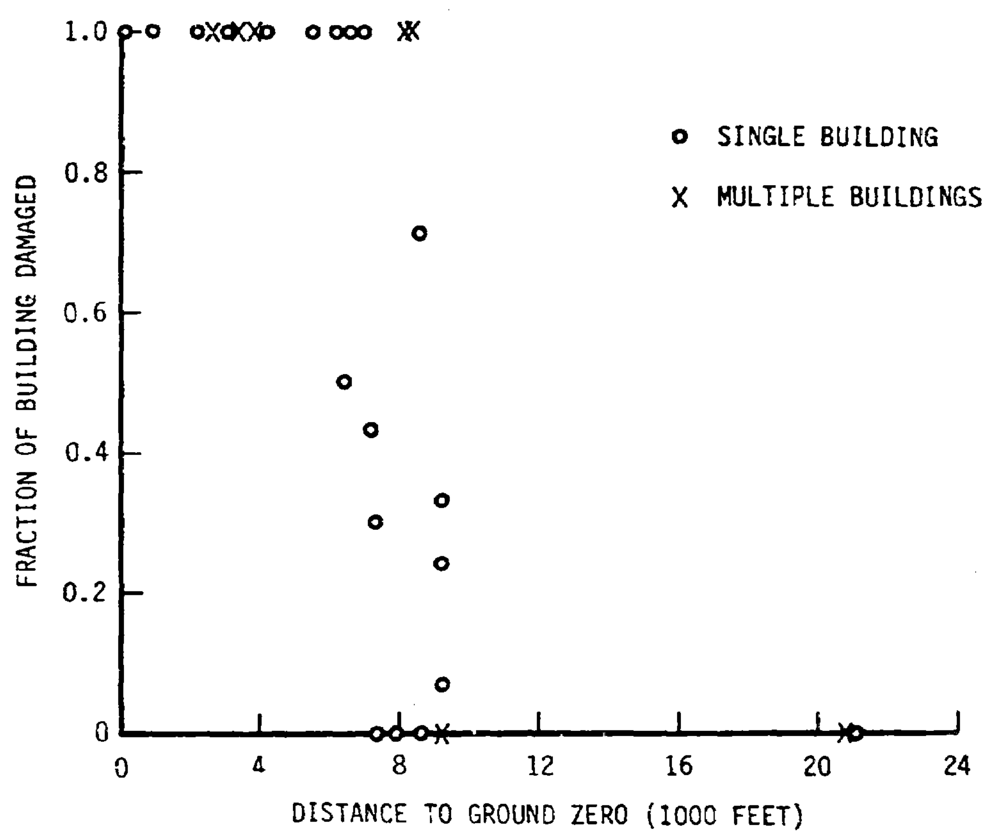


FIGURE 6b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI
ROOF COVER MATERIAL FAILS SLOWLY
SUPERFICIAL DAMAGE CRITERIA

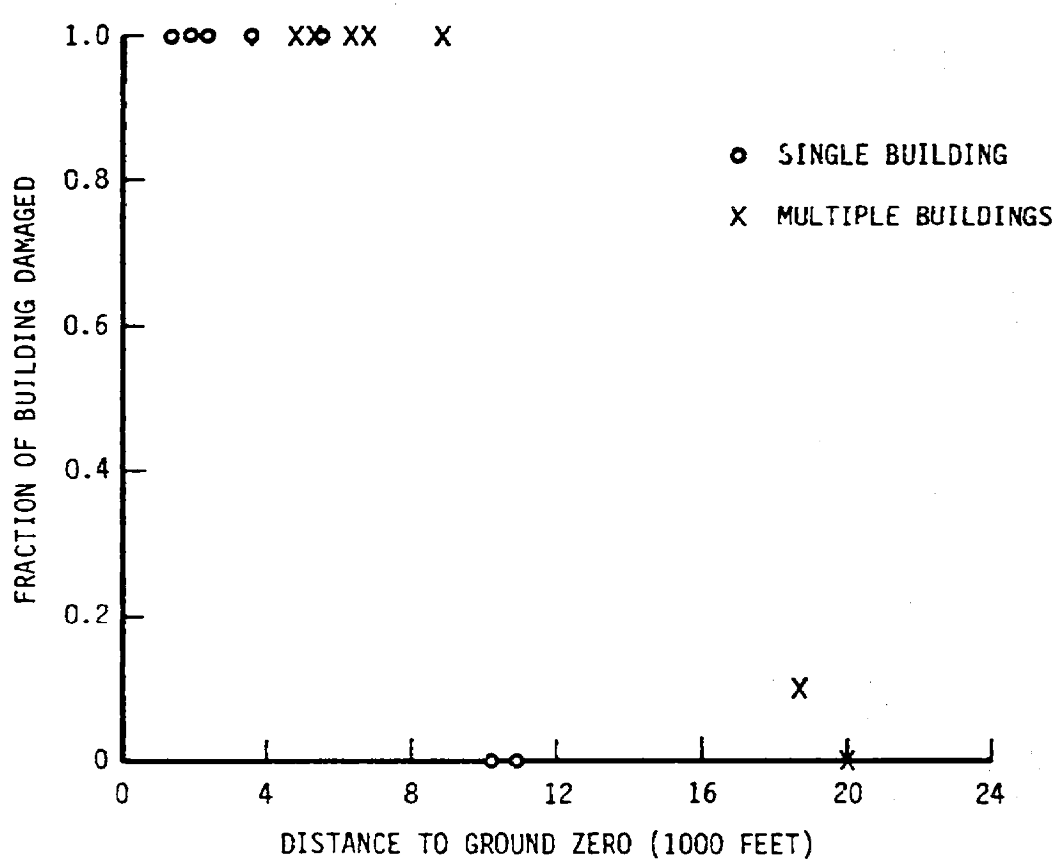


FIGURE 6c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

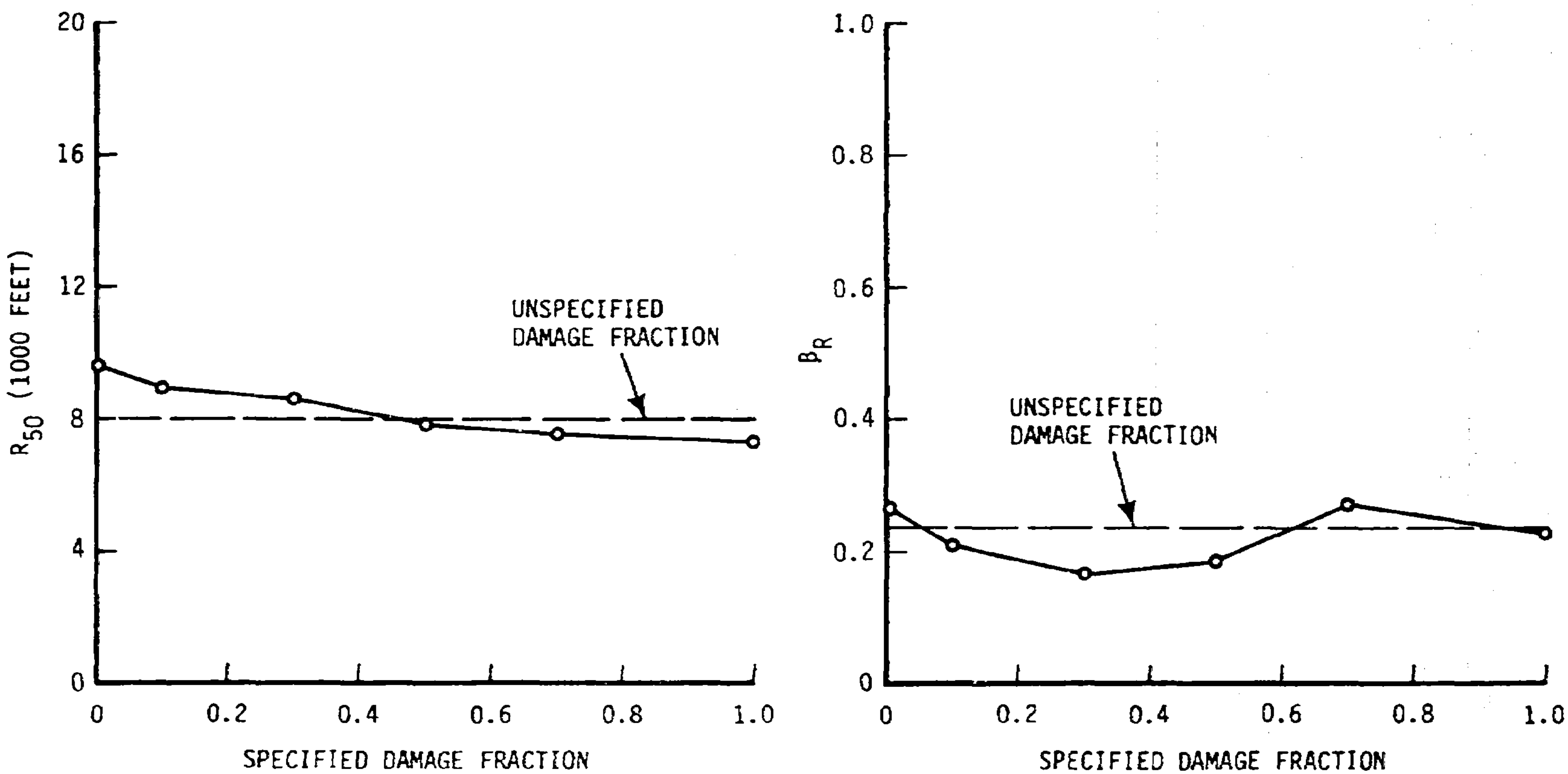


FIGURE 6d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

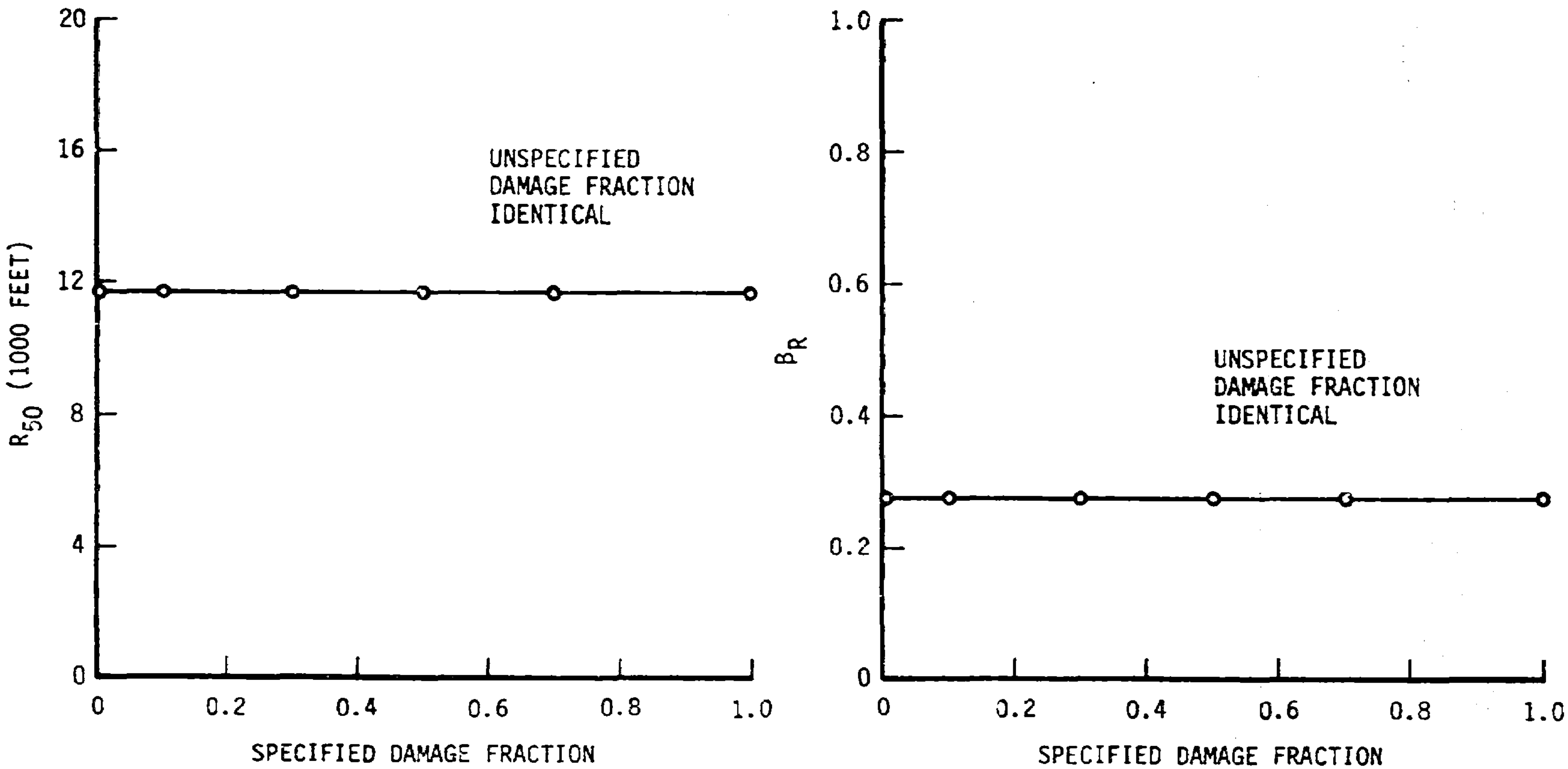


FIGURE 6e

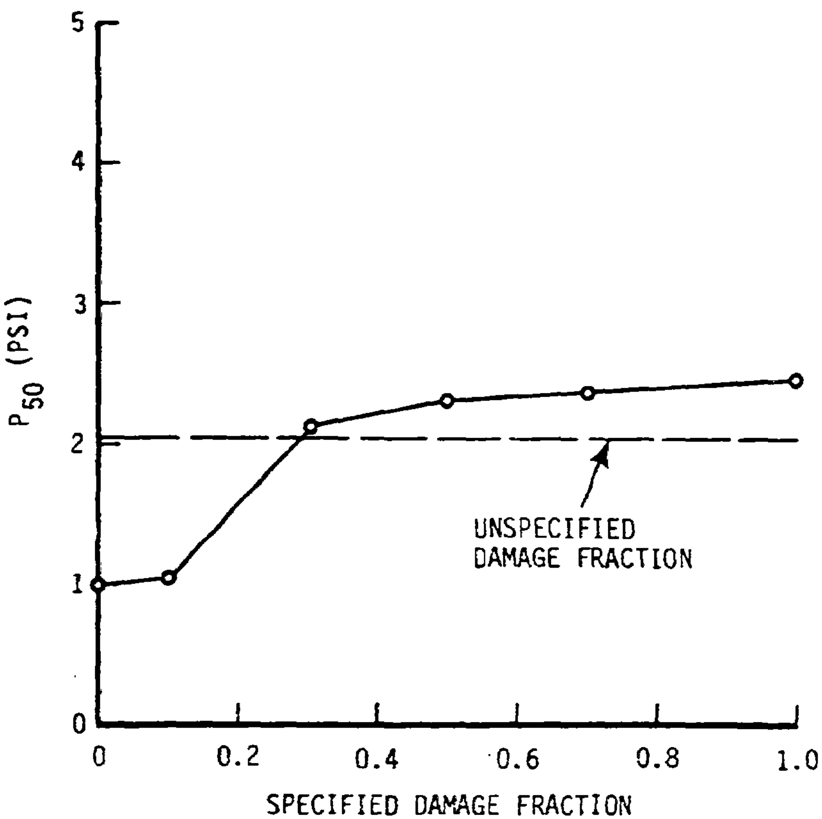
EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT



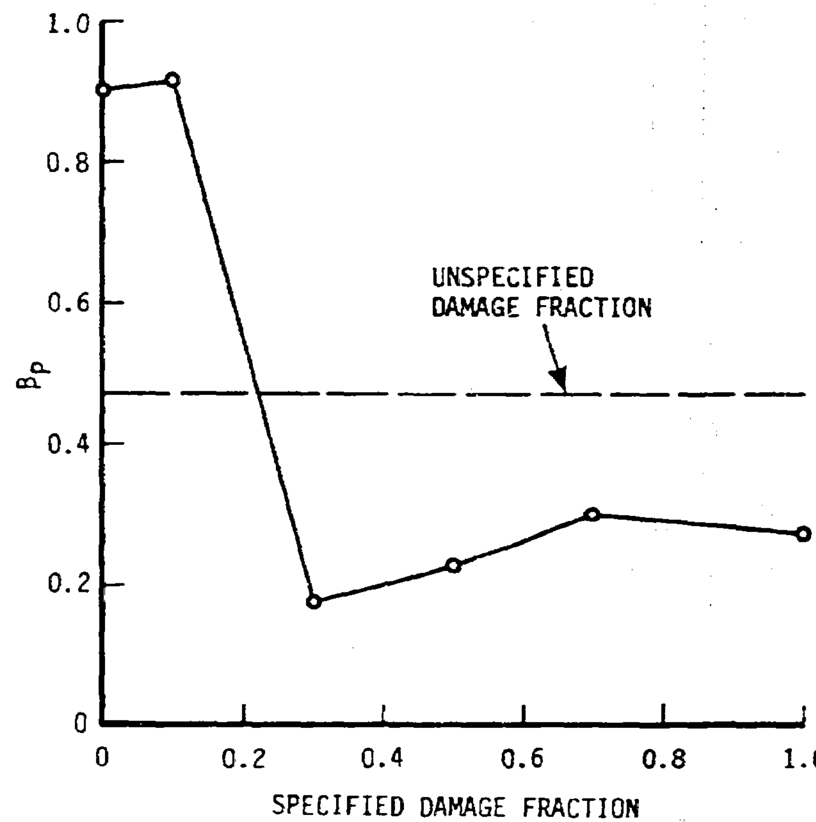


FIGURE 6f

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

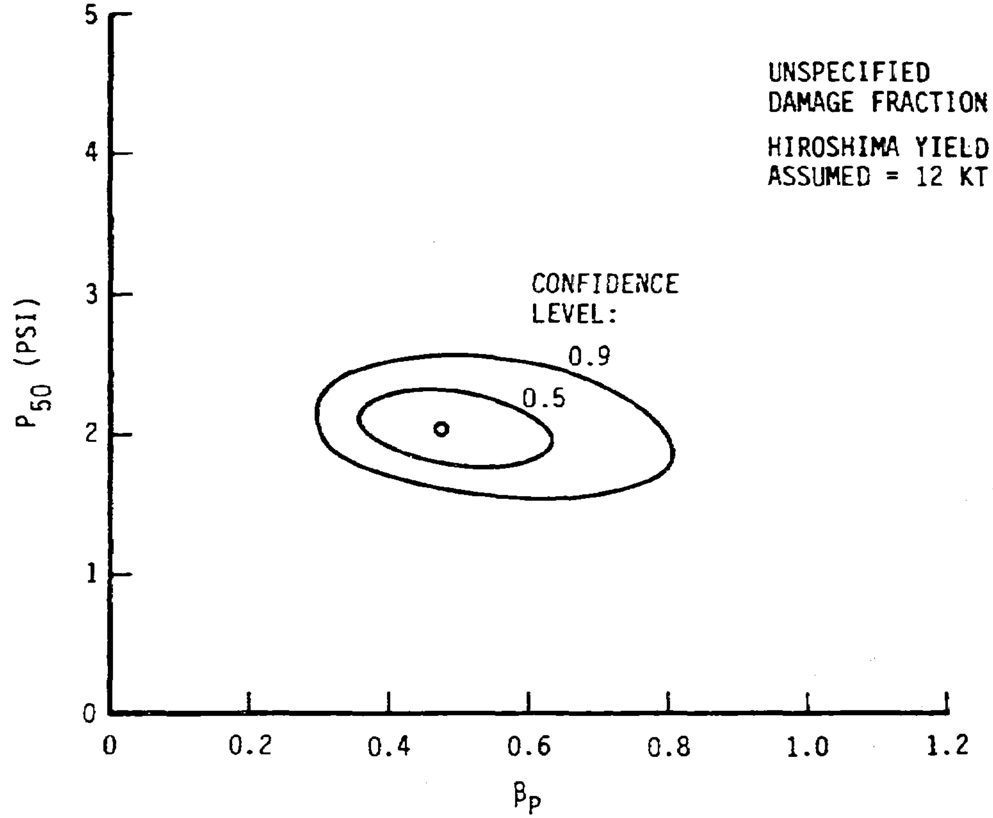


FIGURE 6g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

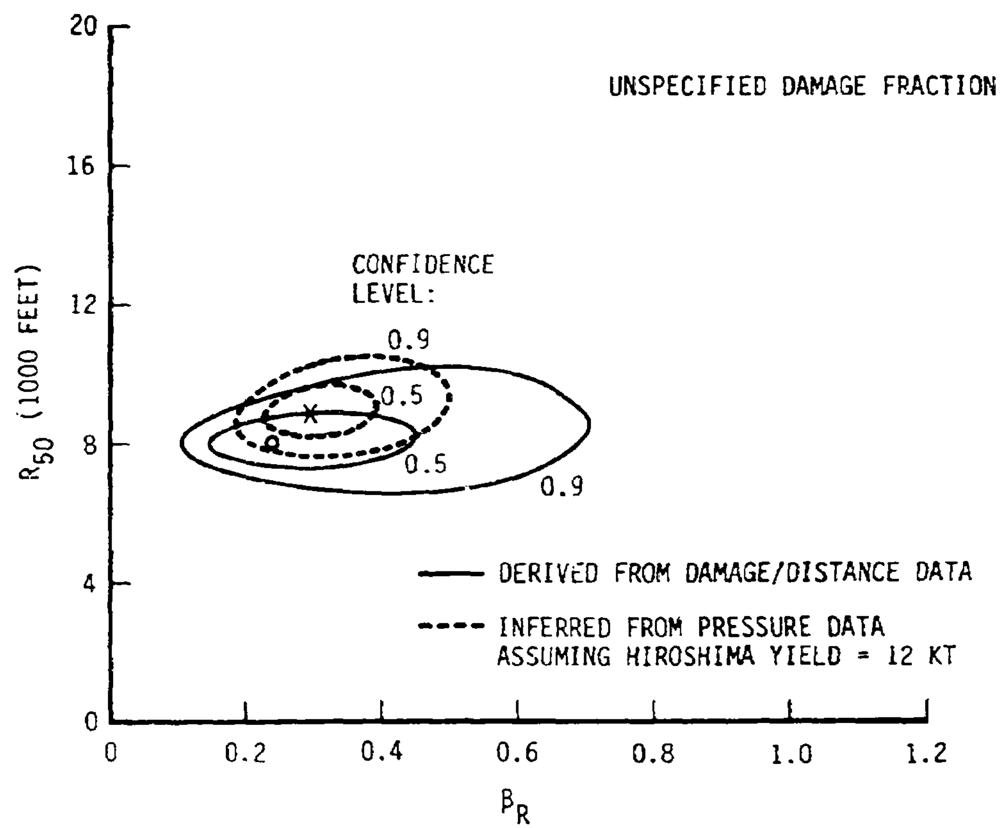


FIGURE 6h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI
ROOF COVER MATERIAL FAILS SLOWLY
SUPERFICIAL DAMAGE CRITERIA

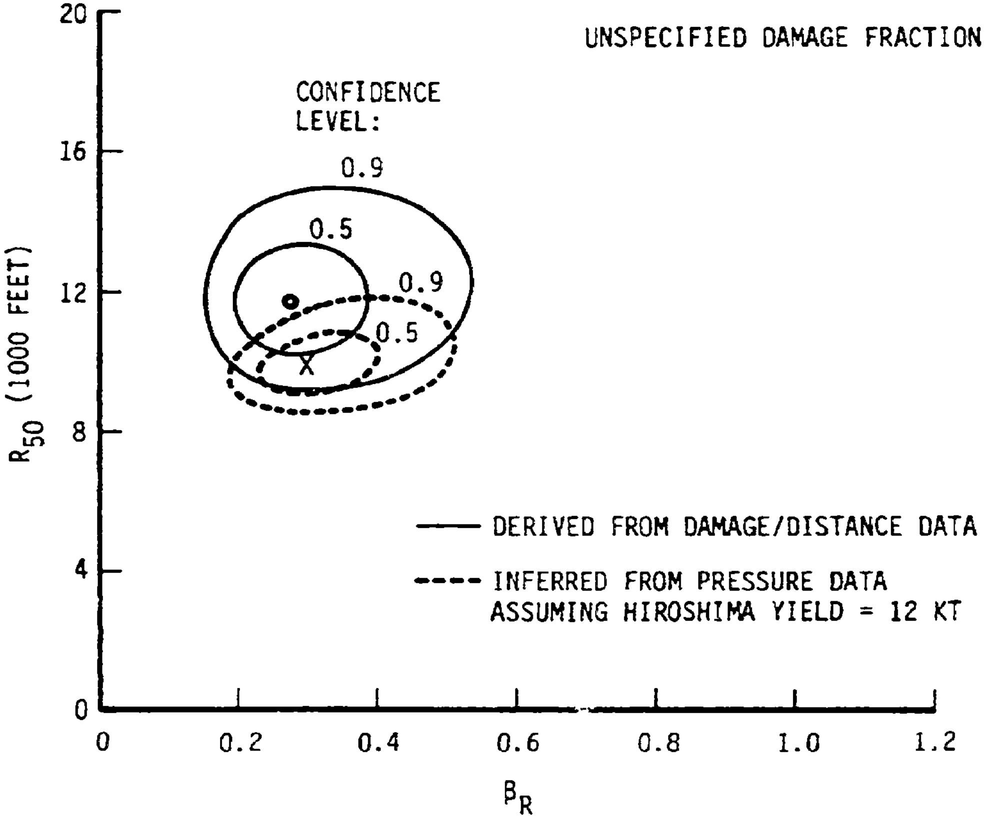


FIGURE 7a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
ROOF COVER MATERIAL FAILS QUICKLY
SUPERFICIAL DAMAGE CRITERIA

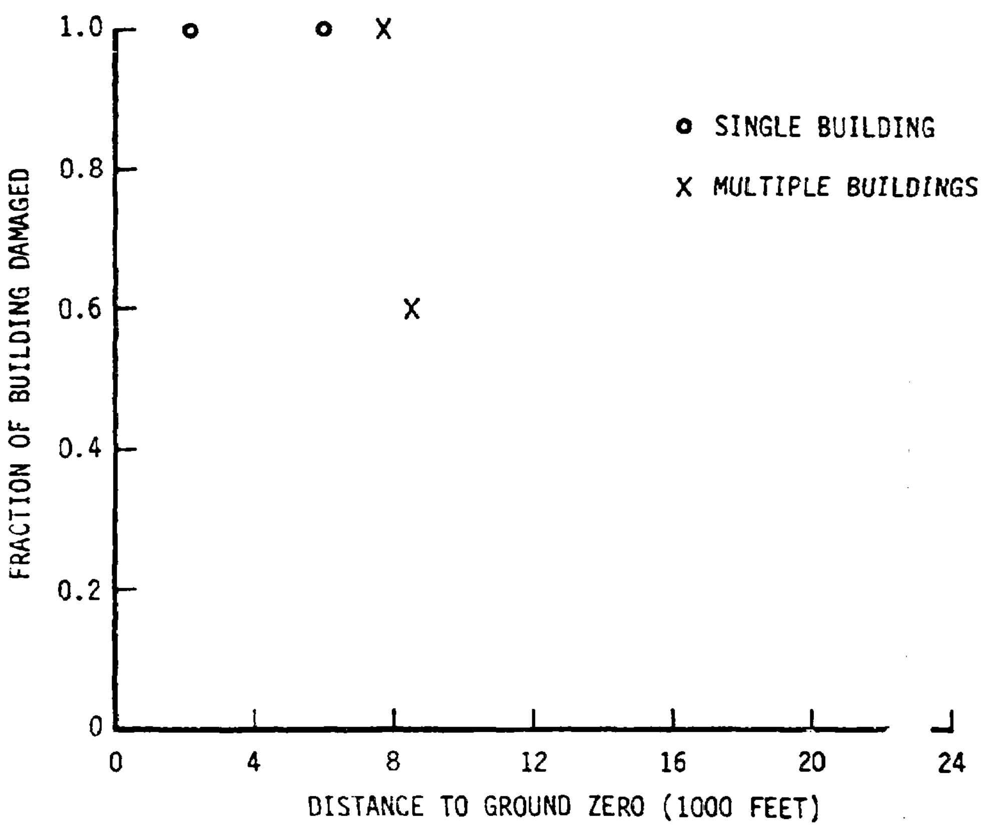


FIGURE 7b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI
ROOF COVER MATERIAL FAILS QUICKLY
SUPERFICIAL DAMAGE CRITERIA

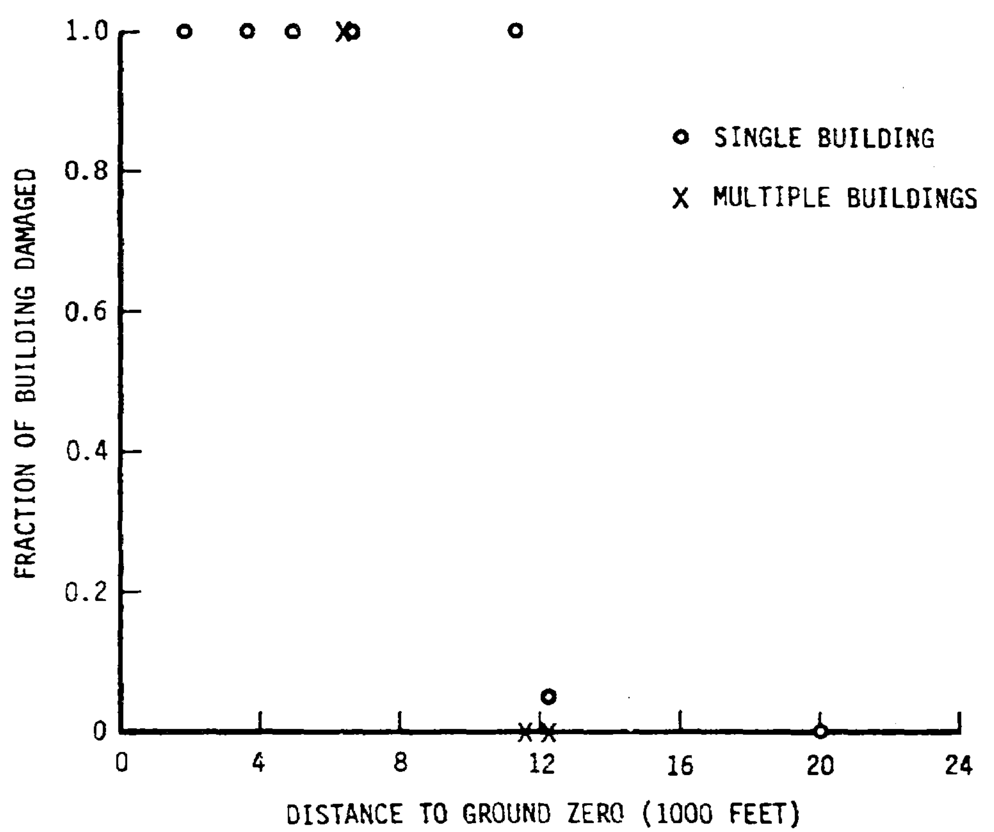


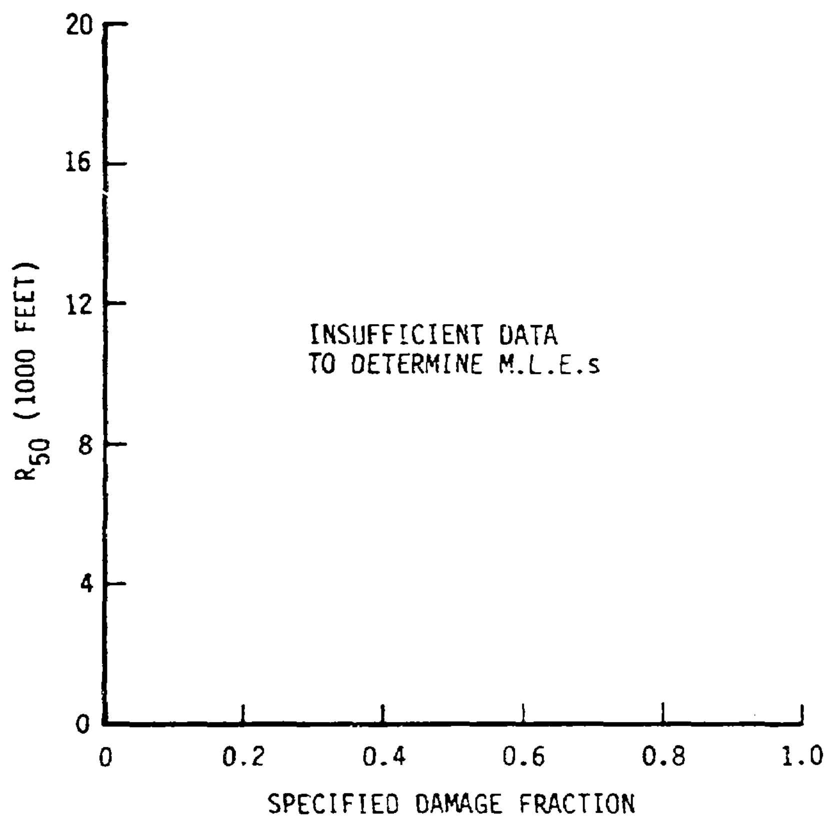
FIGURE 7c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

ROOF COVER MATERIAL FAILS QUICKLY

SUPERFICIAL DAMAGE CRITERIA



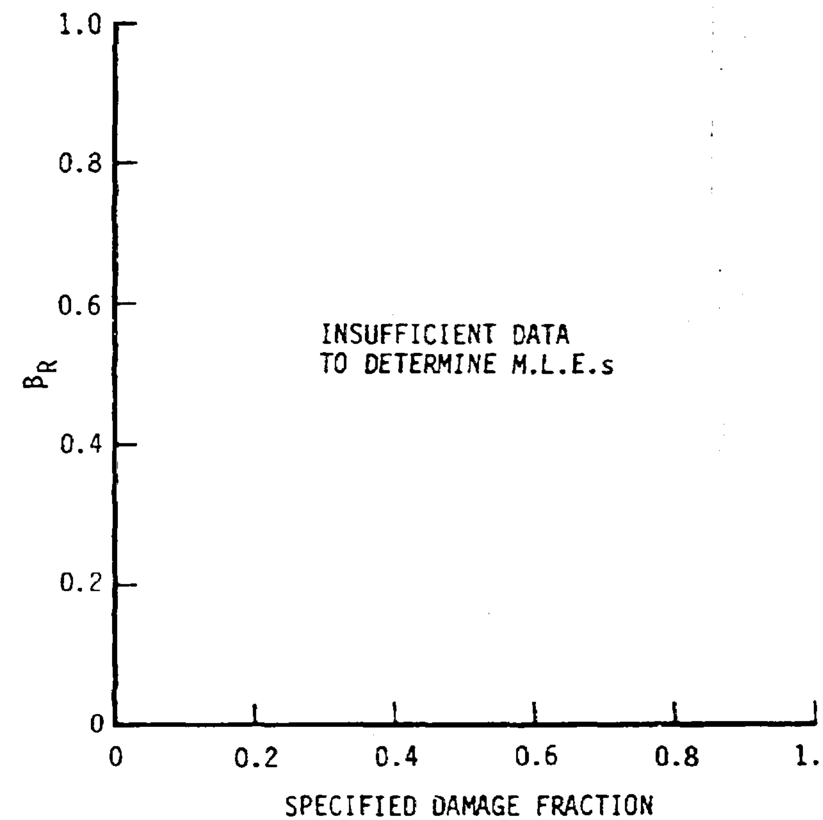


FIGURE 7d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

ROOF COVER MATERIAL FAILS QUICKLY

SUPERFICIAL DAMAGE CRITERIA

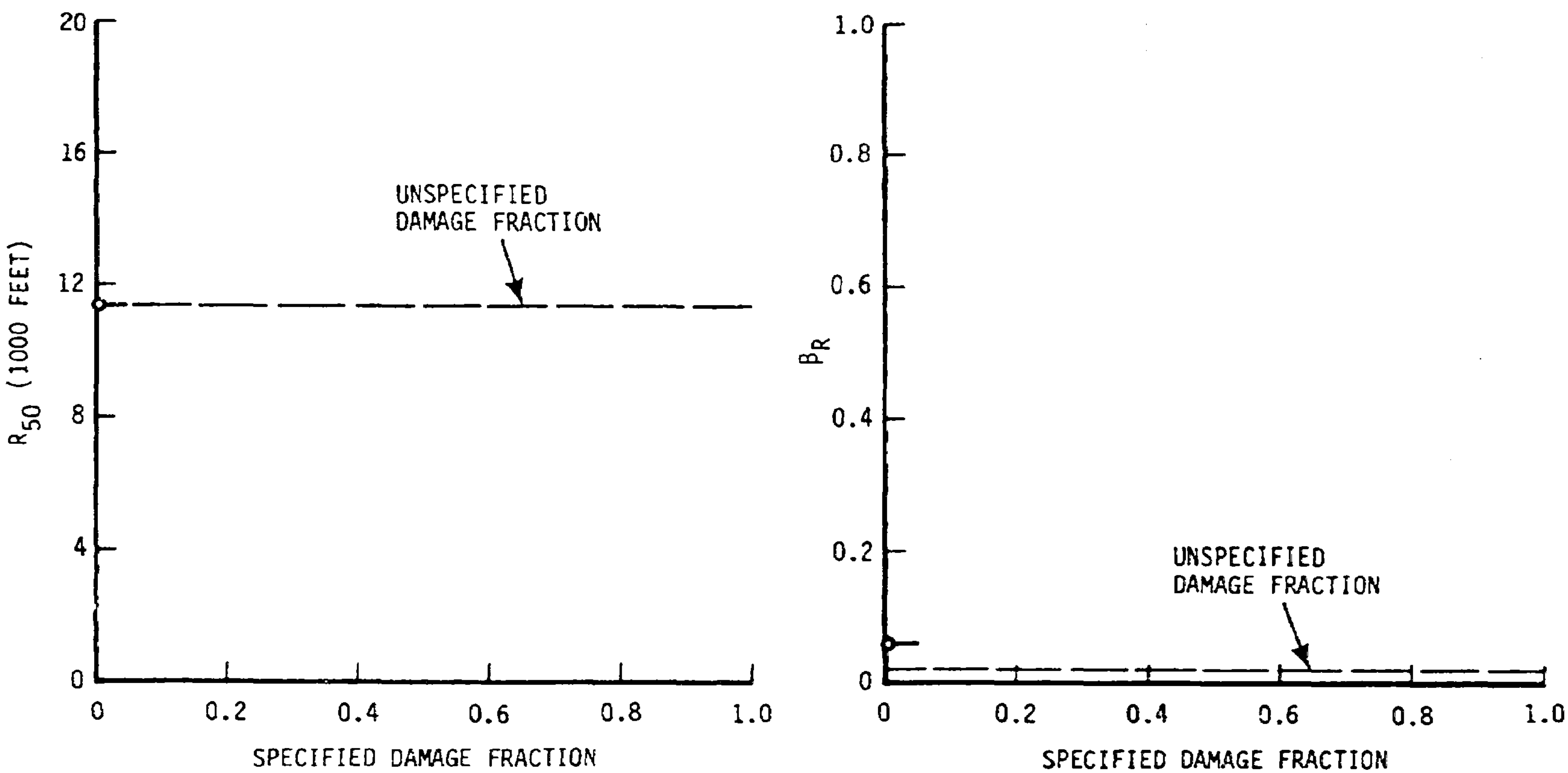


FIGURE 7e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS
ROOF COVER MATERIAL FAILS QUICKLY
SUPERFICIAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT

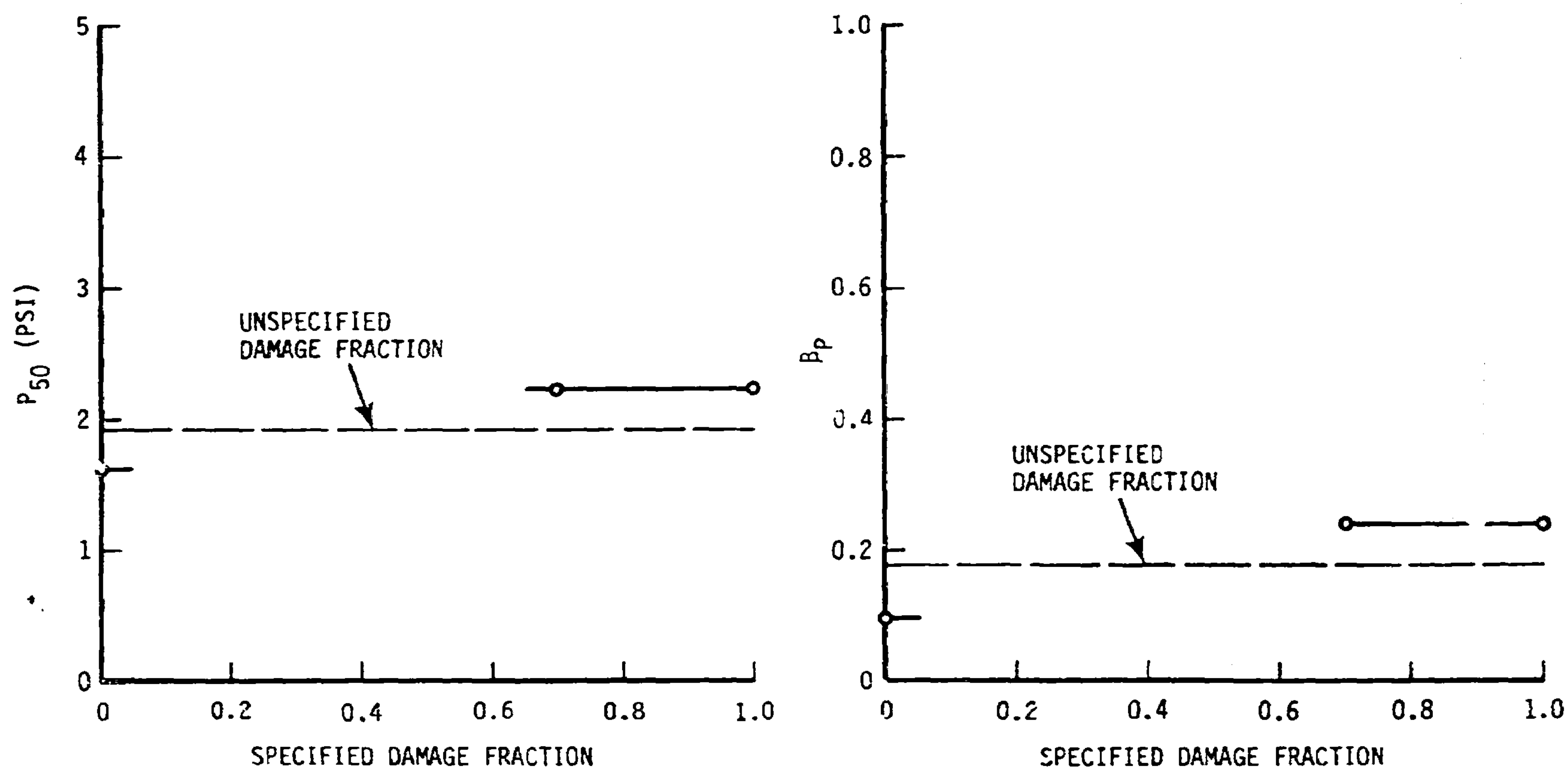


FIGURE 7f

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

ROOF COVER MATERIAL FAILS QUICKLY

SUPERFICIAL DAMAGE CRITERIA

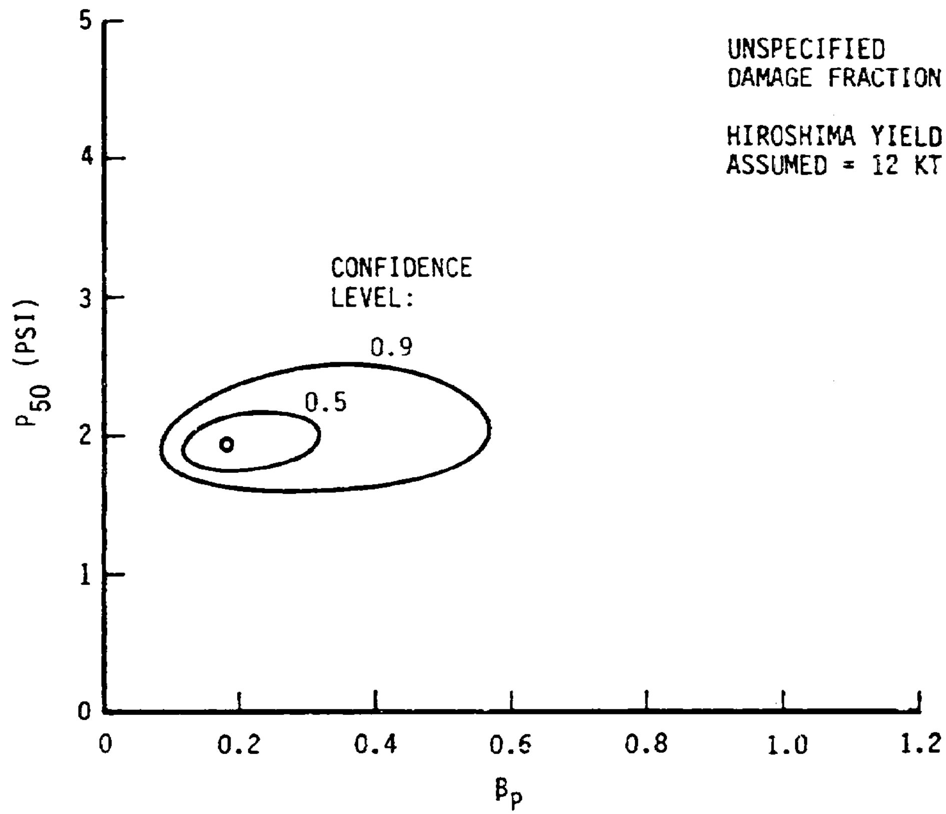


FIGURE 7g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

ROOF COVER MATERIAL FAILS QUICKLY

SUPERFICIAL DAMAGE CRITERIA

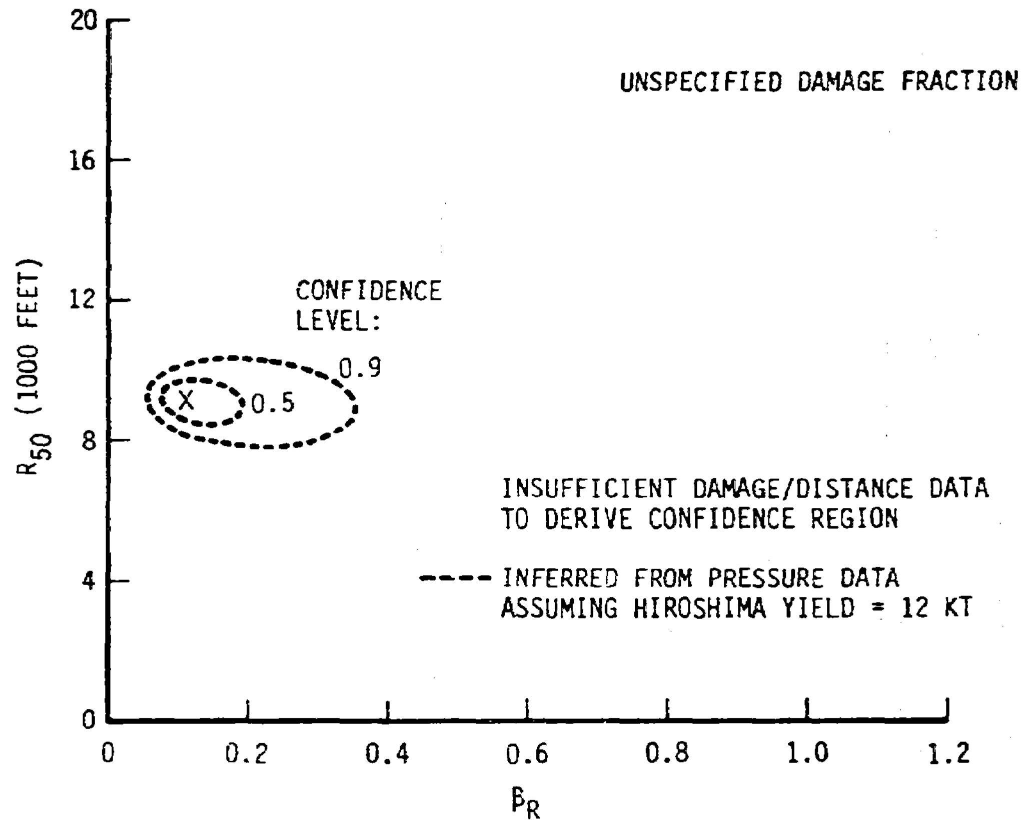


FIGURE 7h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

ROOF COVER MATERIAL FAILS QUICKLY

SUPERFICIAL DAMAGE CRITERIA

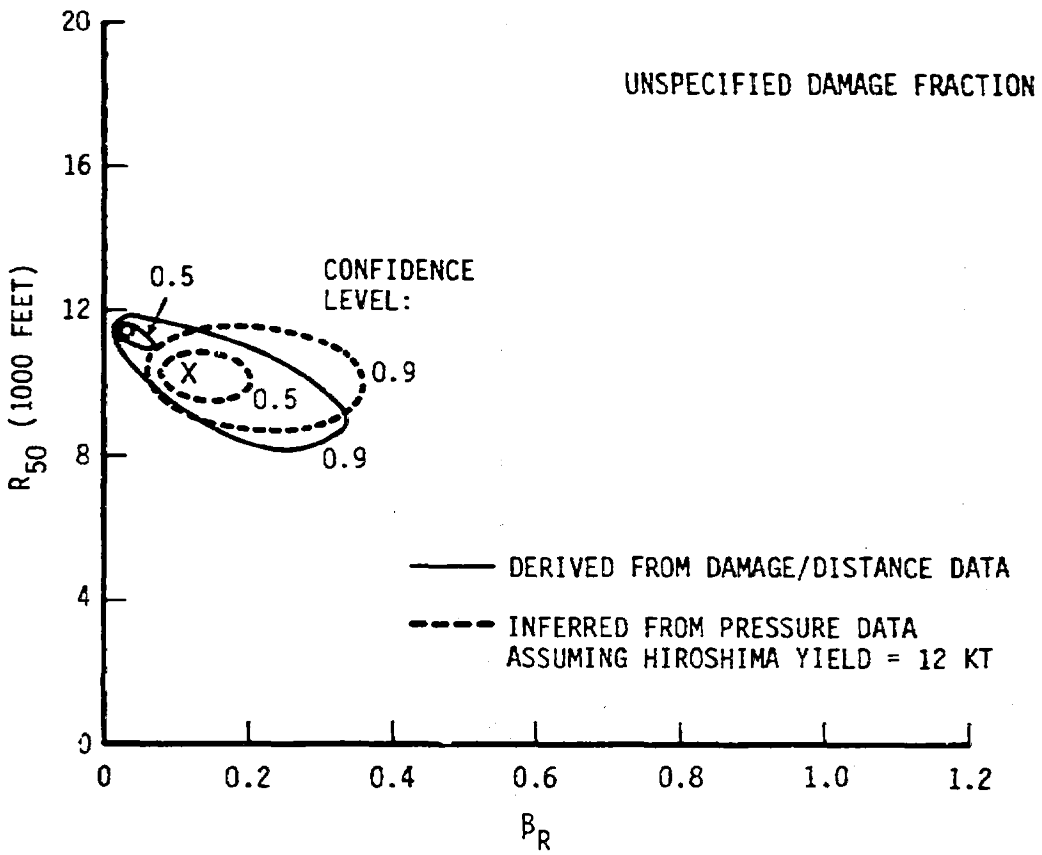


FIGURE 8a

DAMAGE VERSUS DISTANCE DATA

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
STRUCTURAL DAMAGE CRITERIA

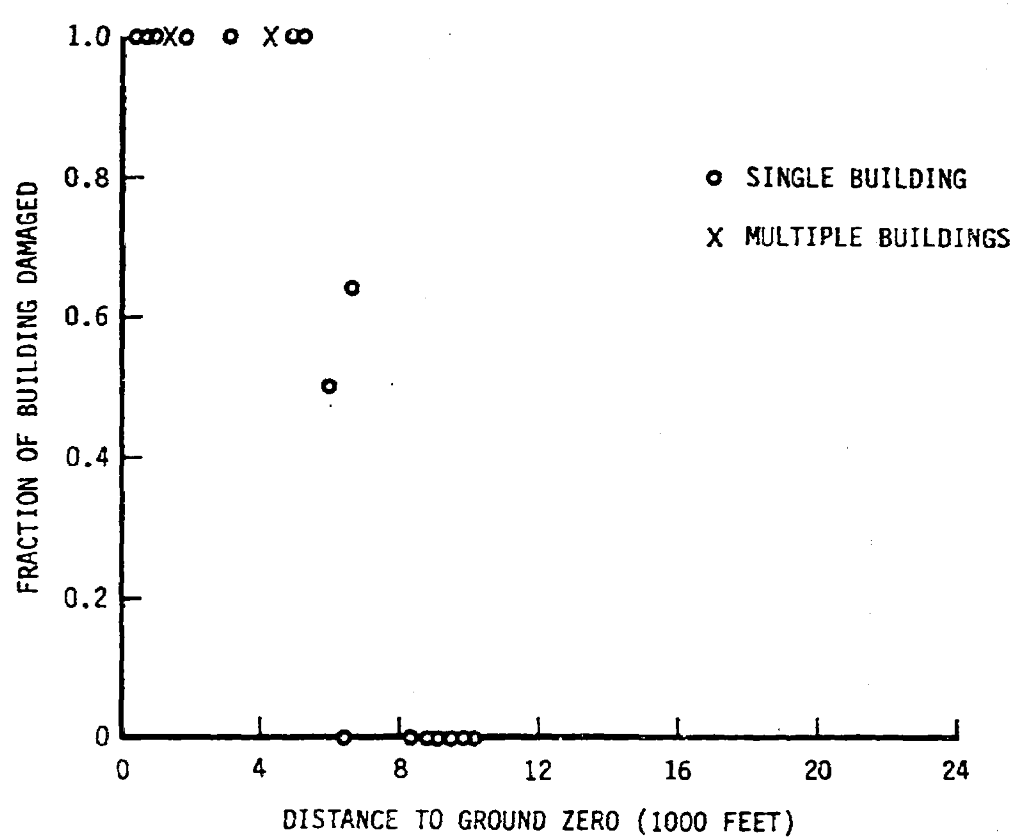


FIGURE 8b

DAMAGE VERSUS DISTANCE DATA

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI
STRUCTURAL DAMAGE CRITERIA

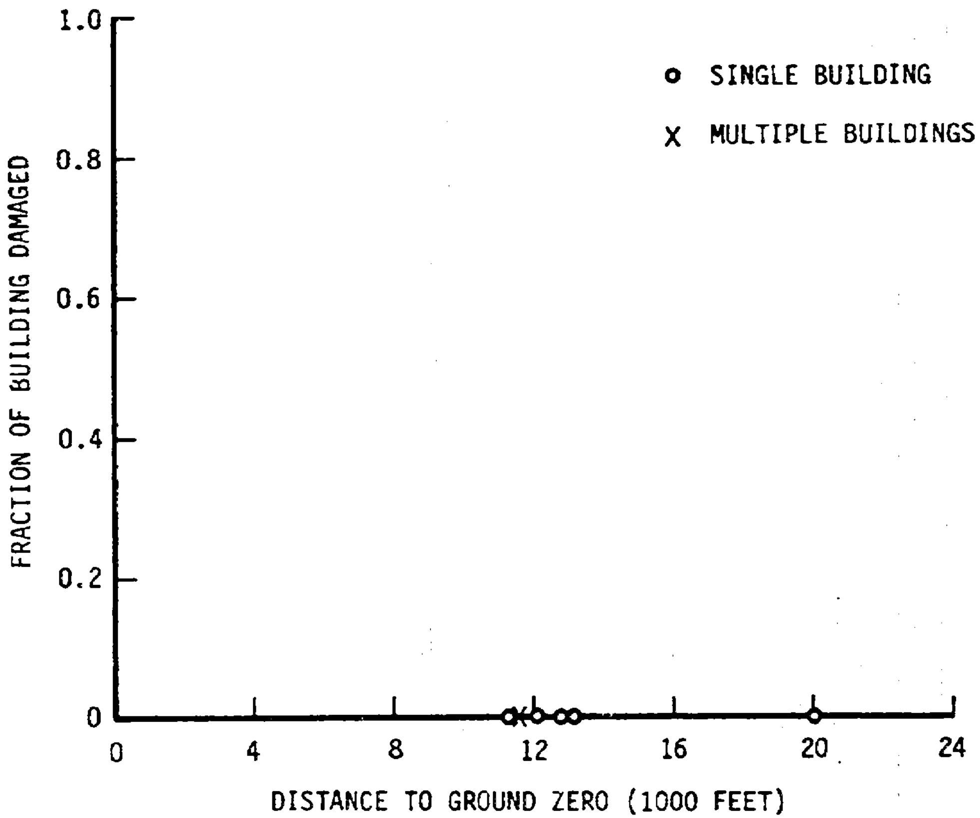


FIGURE 8c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

STRUCTURAL DAMAGE CRITERIA

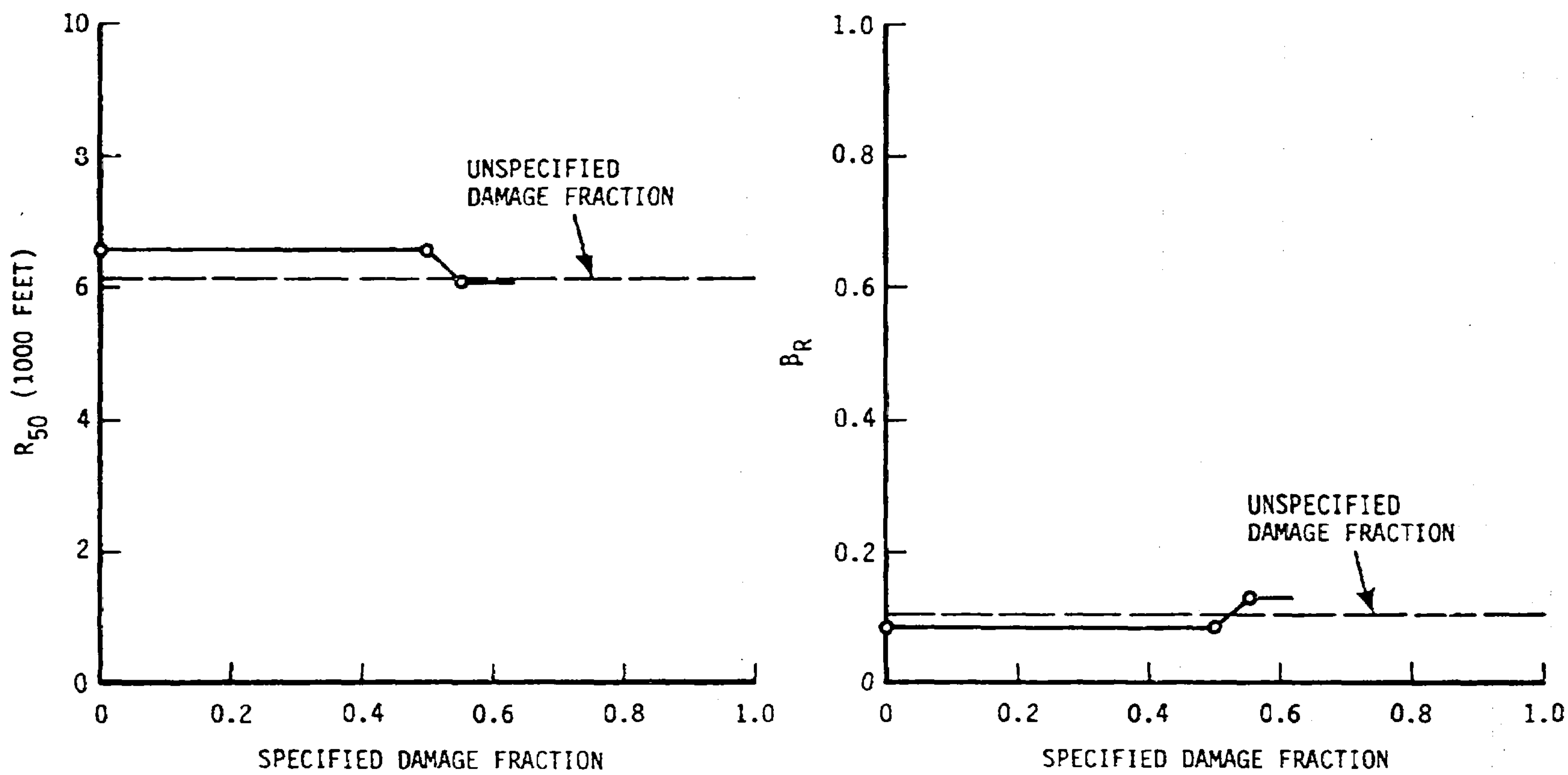


FIGURE 8d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE CRITERIA

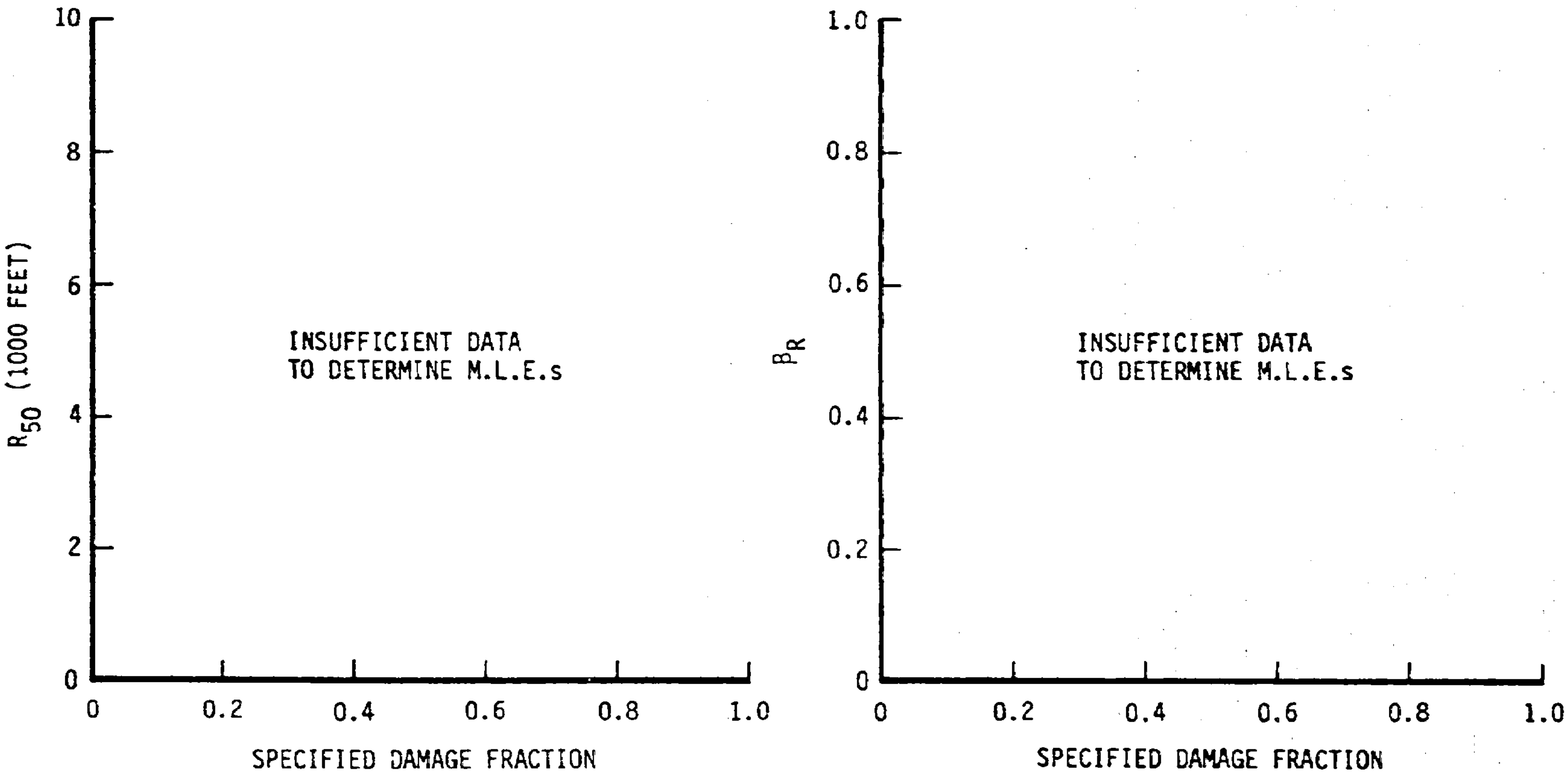
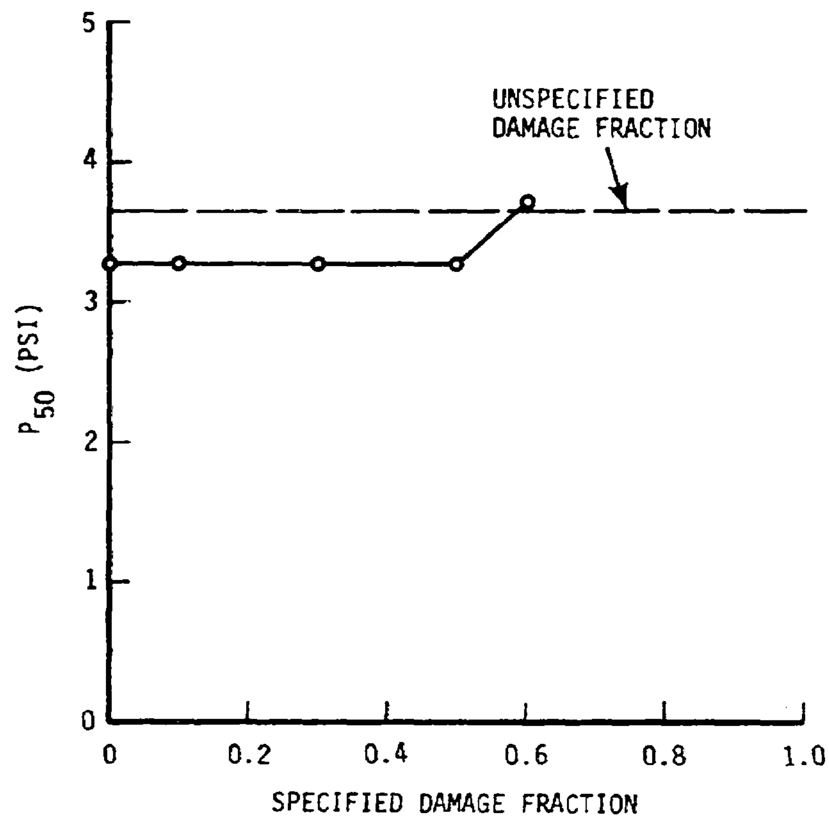


FIGURE 8e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS
STRUCTURAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT



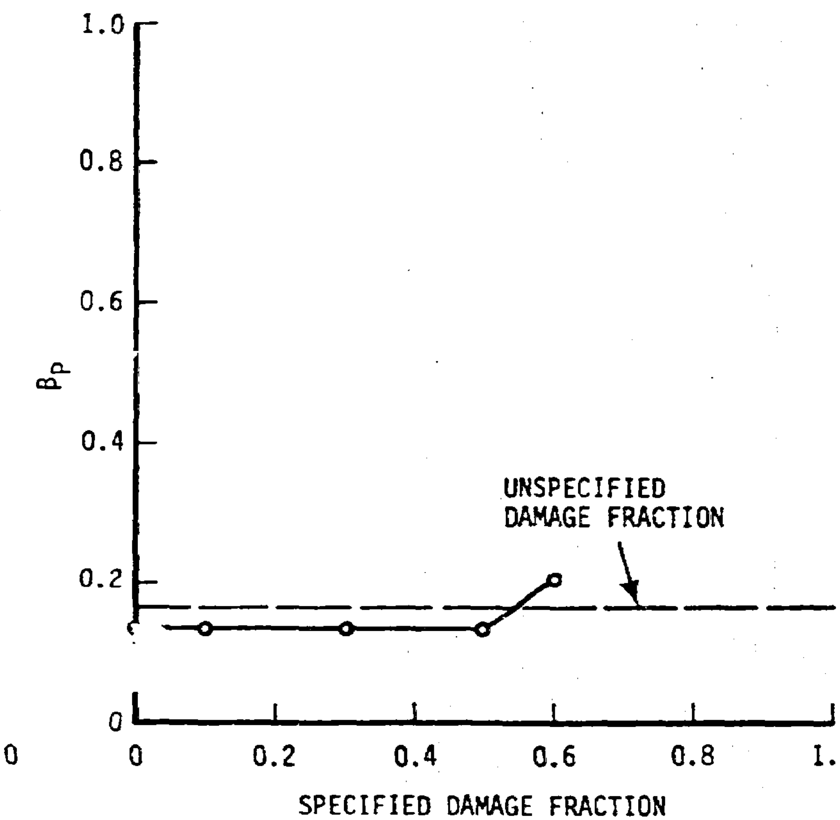


FIGURE 8f

CONFIDENCE REGIONS FOR P_{50} AND β_P

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS

STRUCTURAL DAMAGE CRITERIA

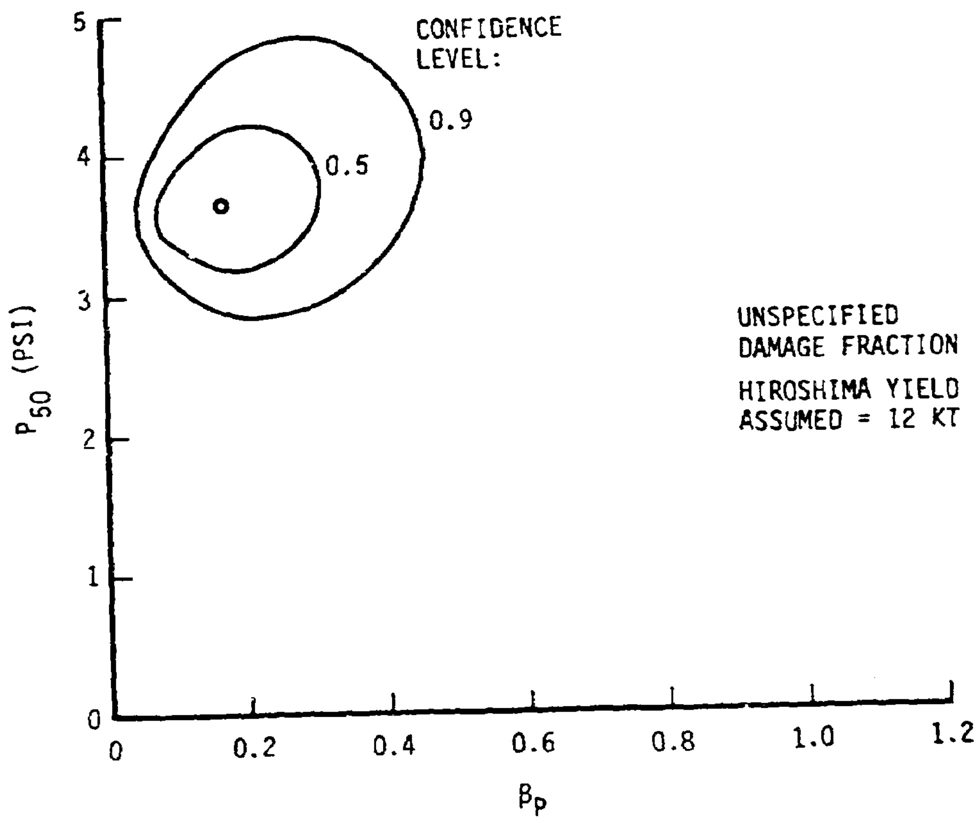


FIGURE 8g

CONFIDENCE REGIONS FOR R_{50} AND β_R

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
STRUCTURAL DAMAGE CRITERIA

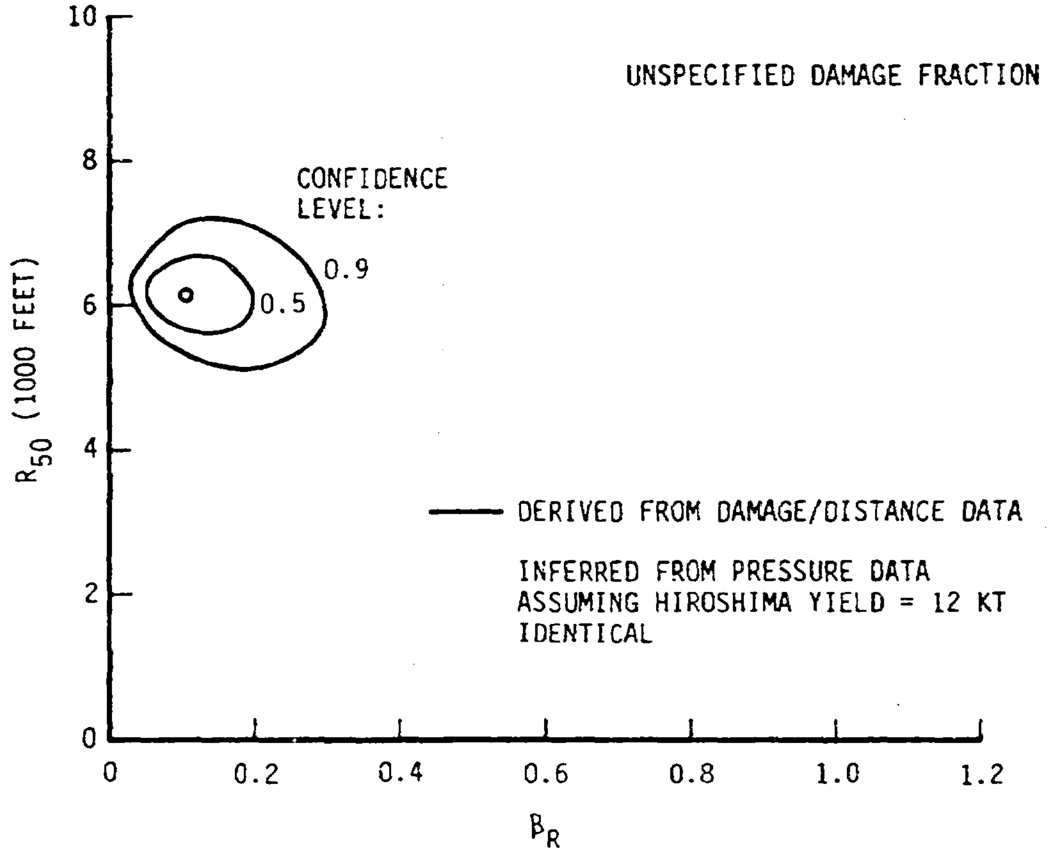


FIGURE 8h

CONFIDENCE REGIONS FOR R_{50} AND β_R

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE CRITERIA

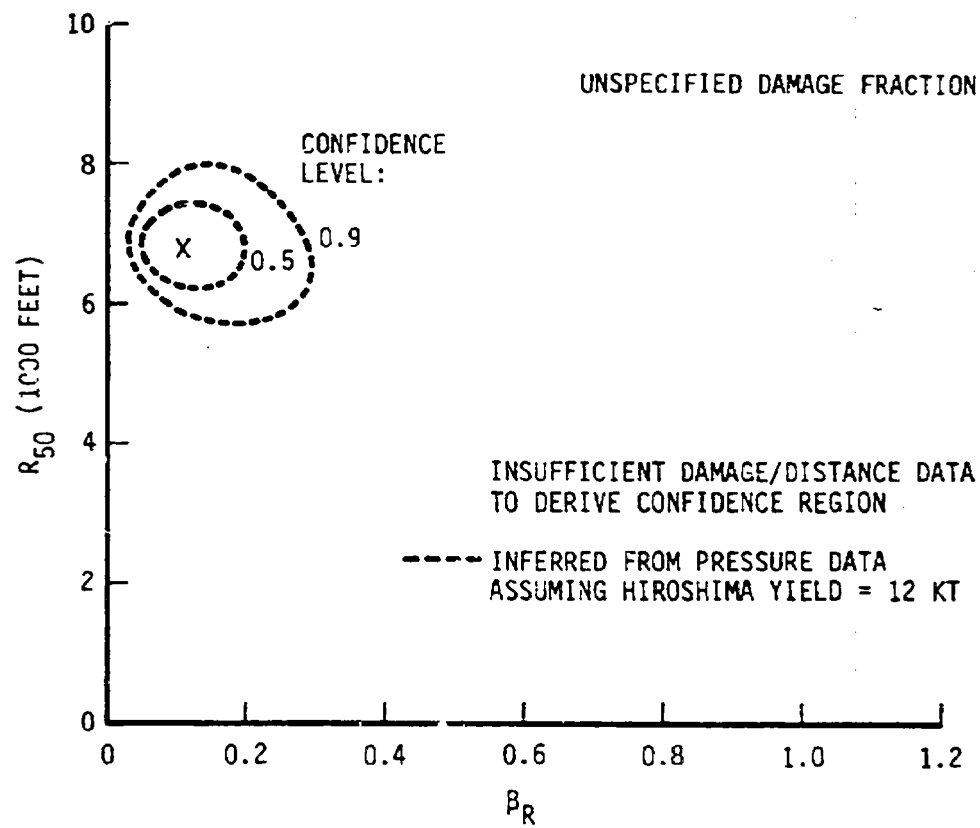


FIGURE 9a

DAMAGE VERSUS DISTANCE DATA

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
STRUCTURAL DAMAGE TO WALLS

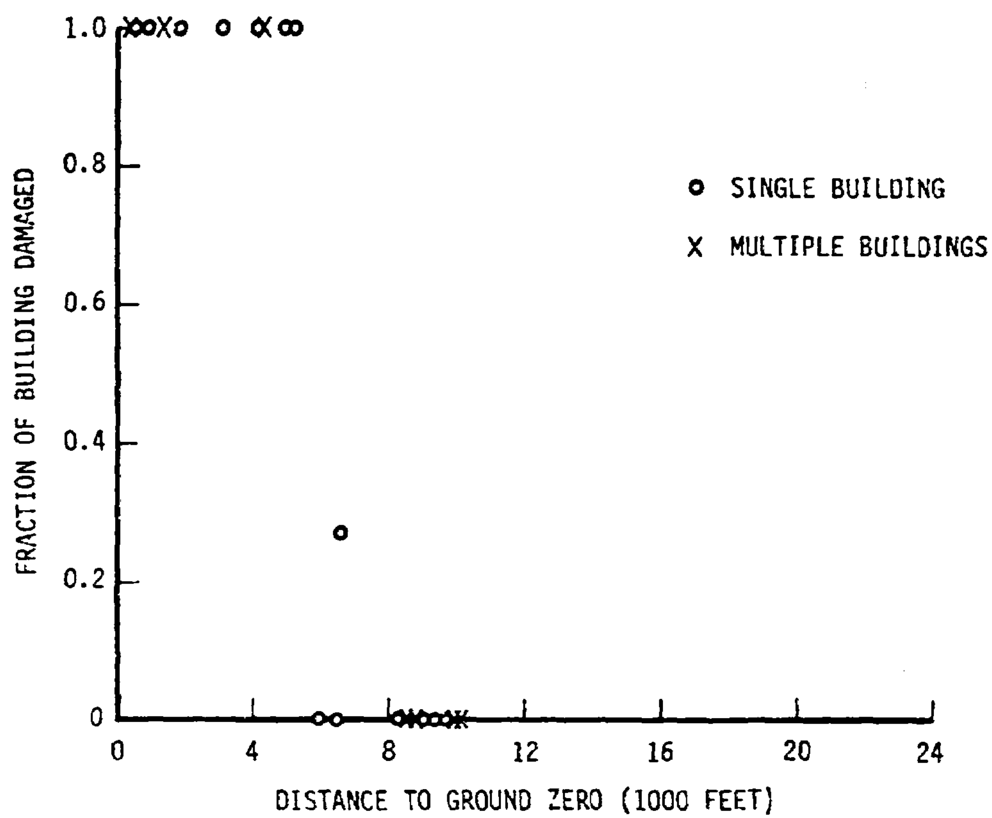


FIGURE 9b

DAMAGE VERSUS DISTANCE DATA

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI
STRUCTURAL DAMAGE TO WALLS

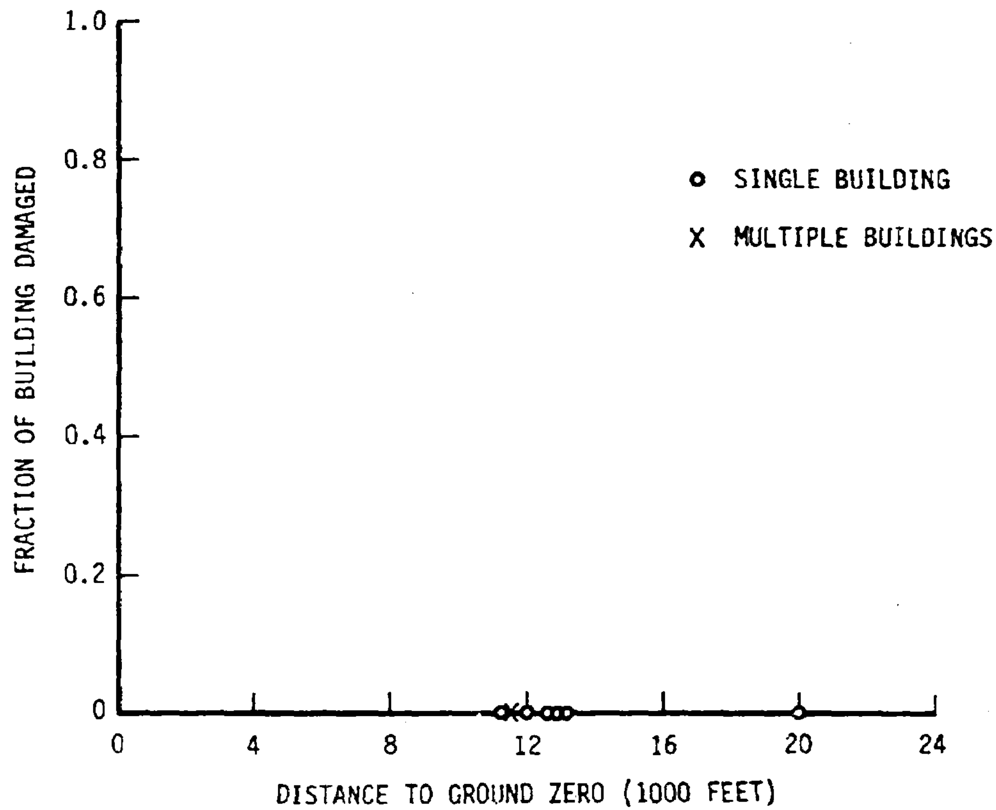


FIGURE 9c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND B_R

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

STRUCTURAL DAMAGE TO WALLS

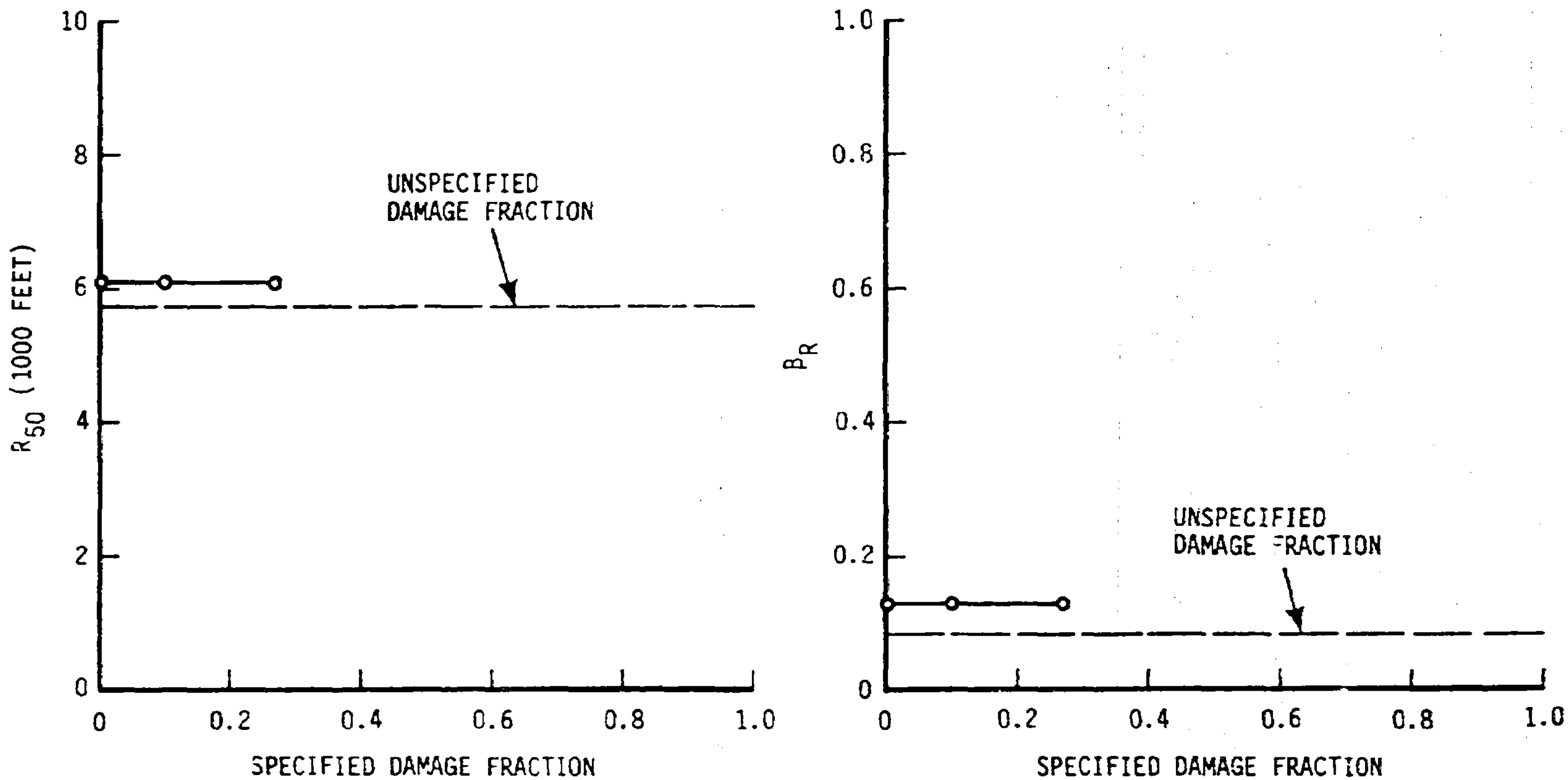


FIGURE 9d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE TO WALLS

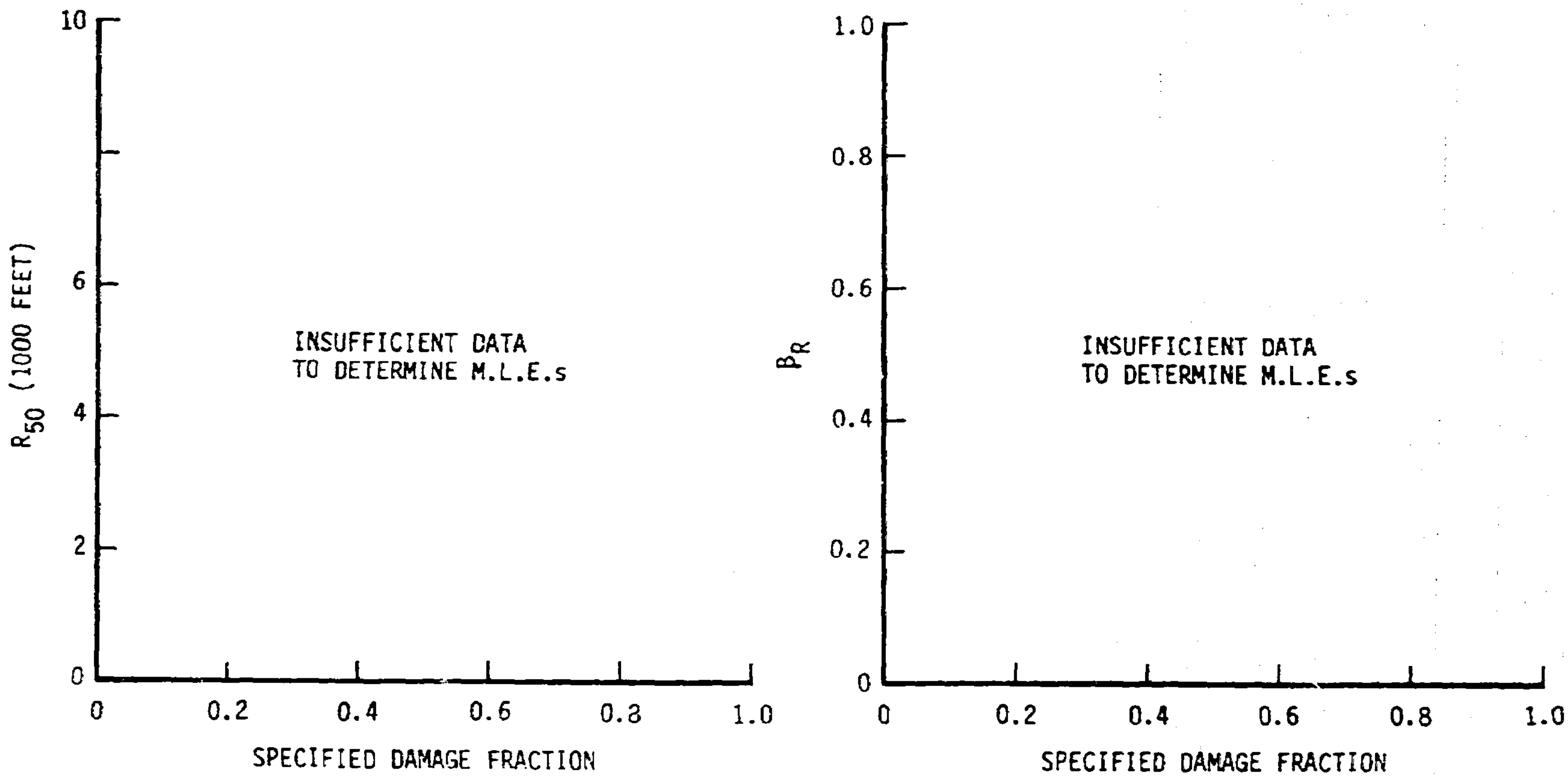


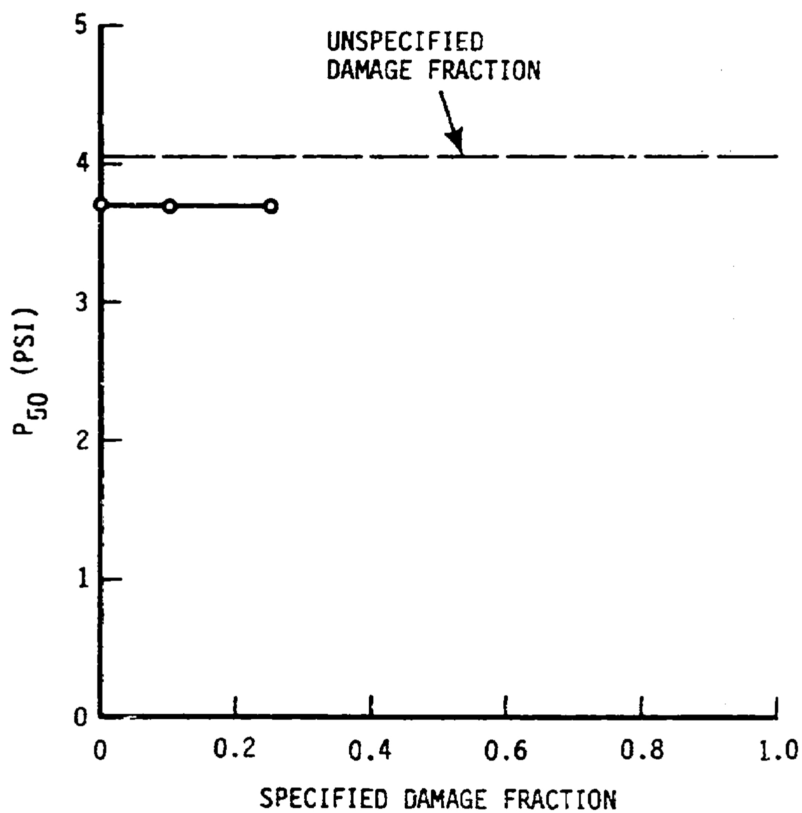
FIGURE 9e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS

STRUCTURAL DAMAGE TO WALLS

HIROSHIMA YIELD ASSUMED = 12 KT



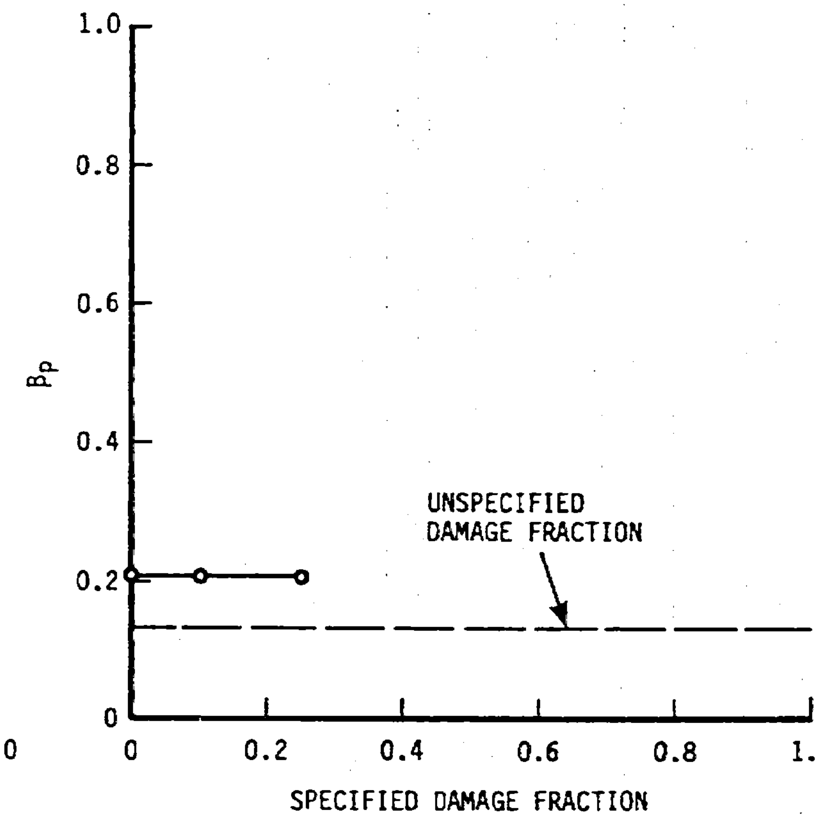


FIGURE 9f

CONFIDENCE REGIONS FOR P_{50} AND β_P

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS

STRUCTURAL DAMAGE TO WALLS

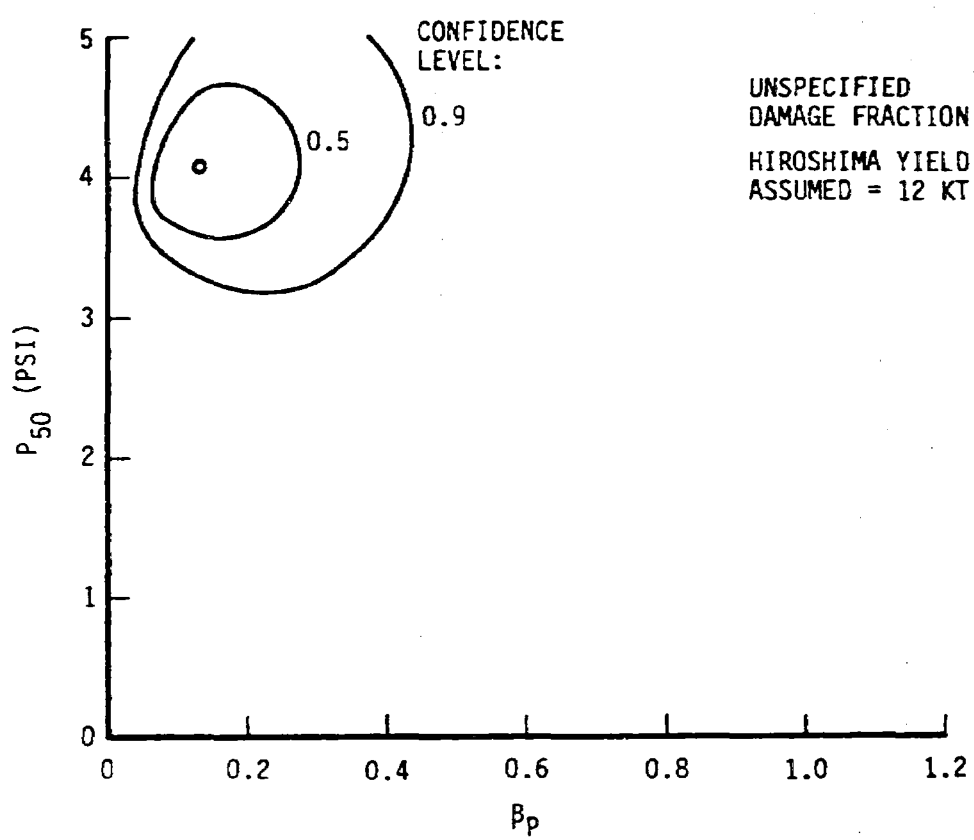


FIGURE 9g

CONFIDENCE REGIONS FOR R_{50} AND β_R

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

STRUCTURAL DAMAGE TO WALLS

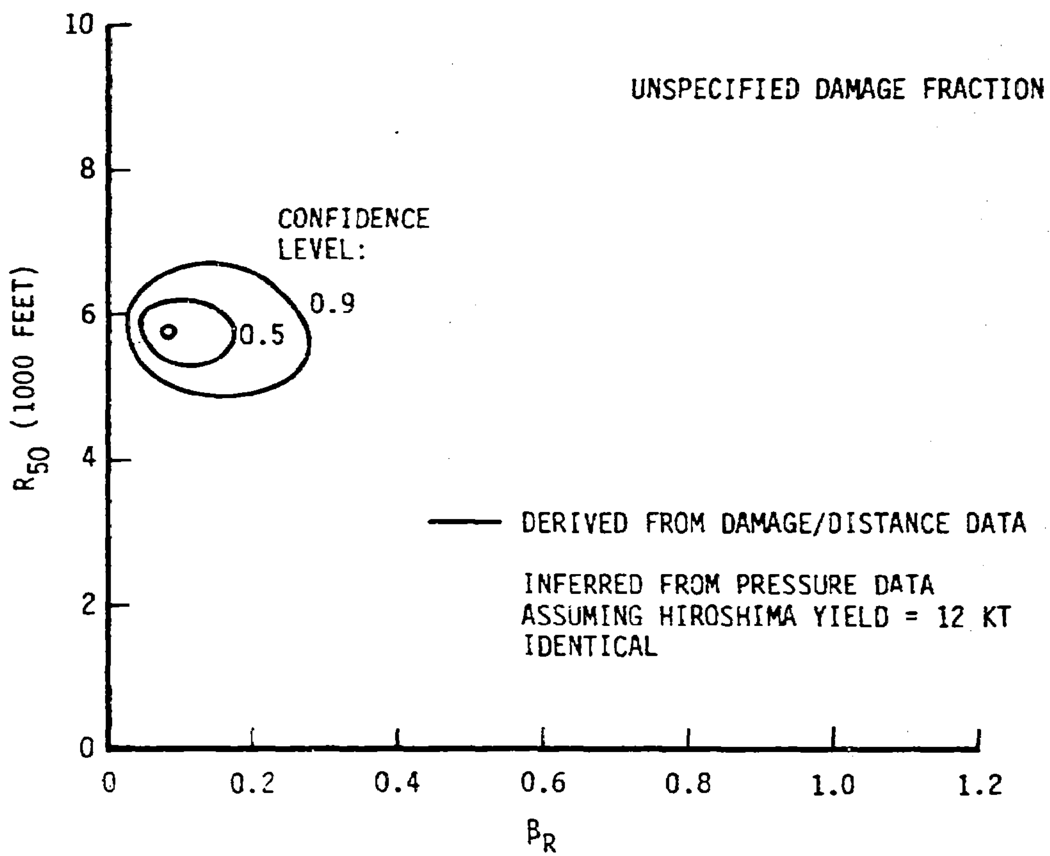


FIGURE 9h

CONFIDENCE REGIONS FOR R_{50} AND β_R

MULTISTORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE TO WALLS

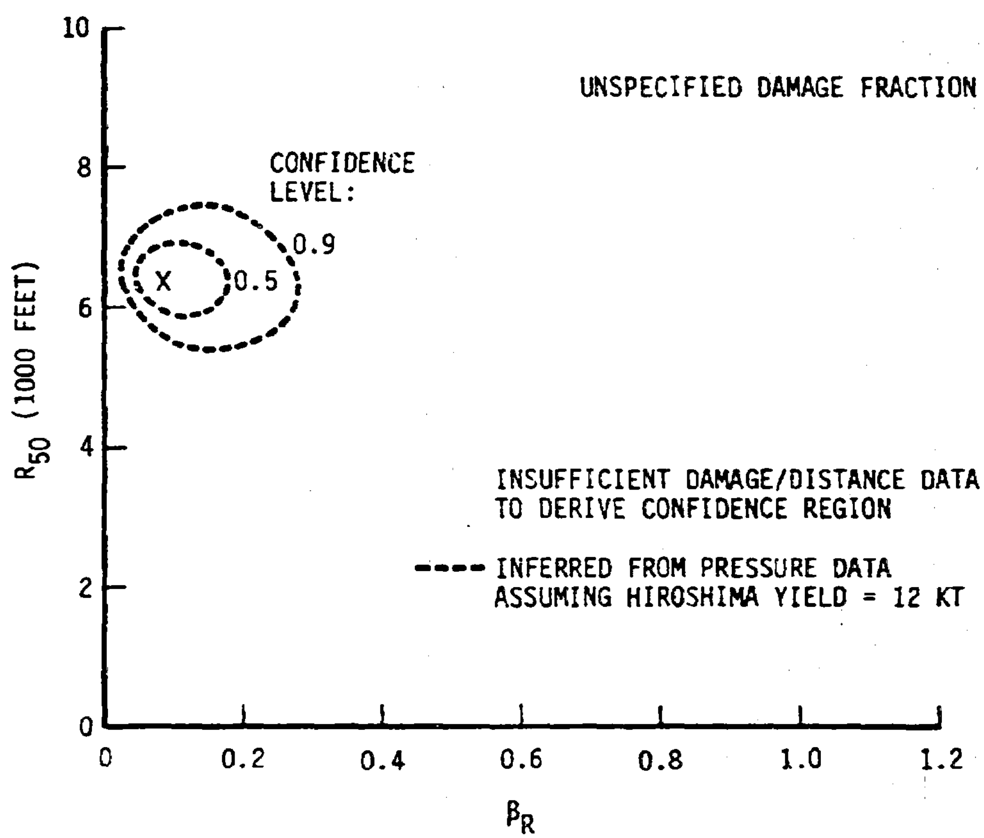


FIGURE 10a

DAMAGE VERSUS DISTANCE DATA

MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
WALL THICKNESS OF 7 TO 14 INCHES
STRUCTURAL DAMAGE TO WALLS

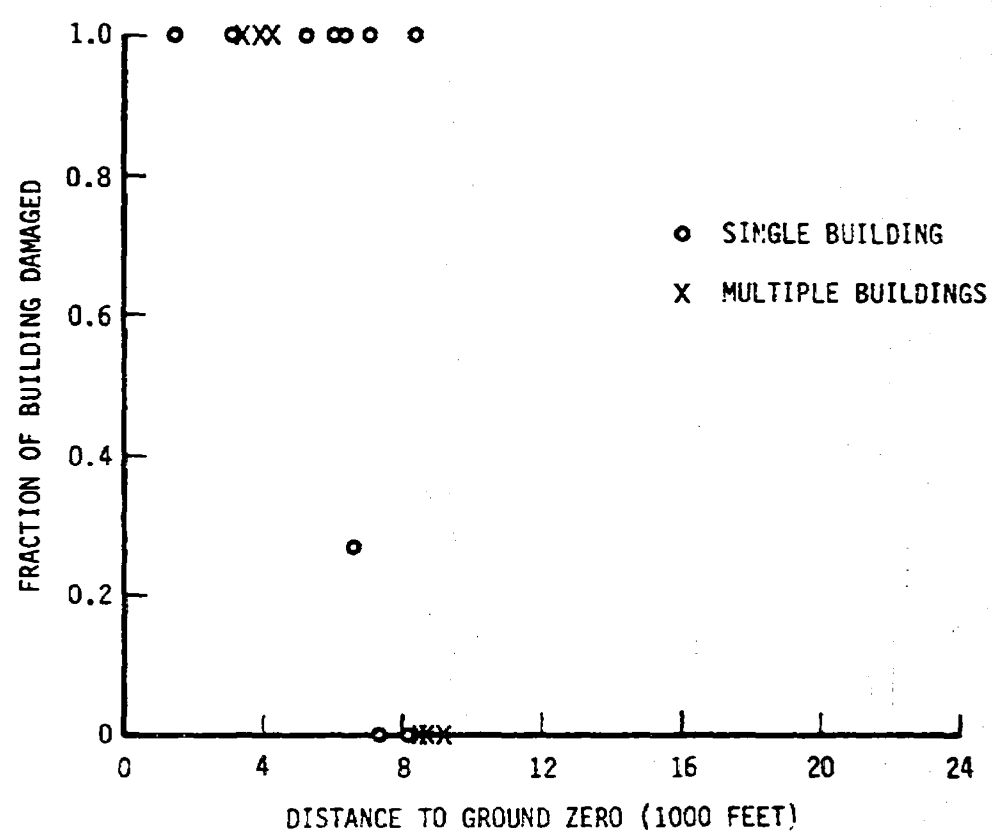


FIGURE 10b

DAMAGE VERSUS DISTANCE DATA

MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI
WALL THICKNESS OF 7 TO 14 INCHES
STRUCTURAL DAMAGE TO WALLS

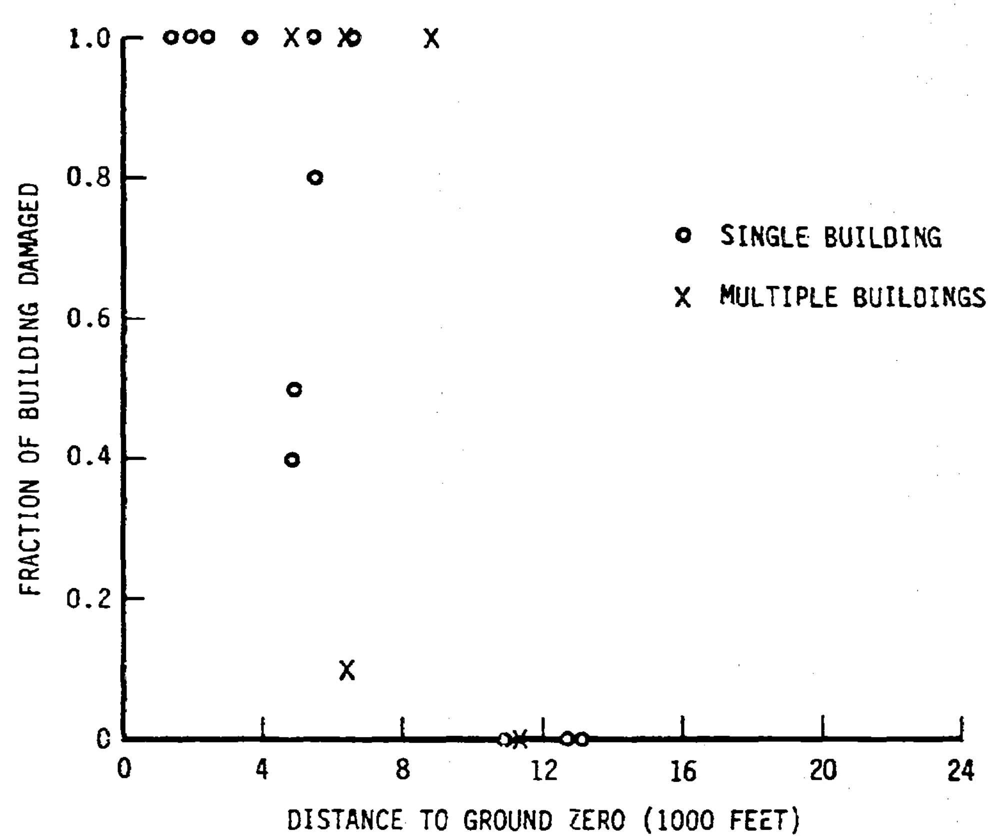


FIGURE 10c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND B_R

MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

WALL THICKNESS OF 7 TO 14 INCHES

STRUCTURAL DAMAGE TO WALLS

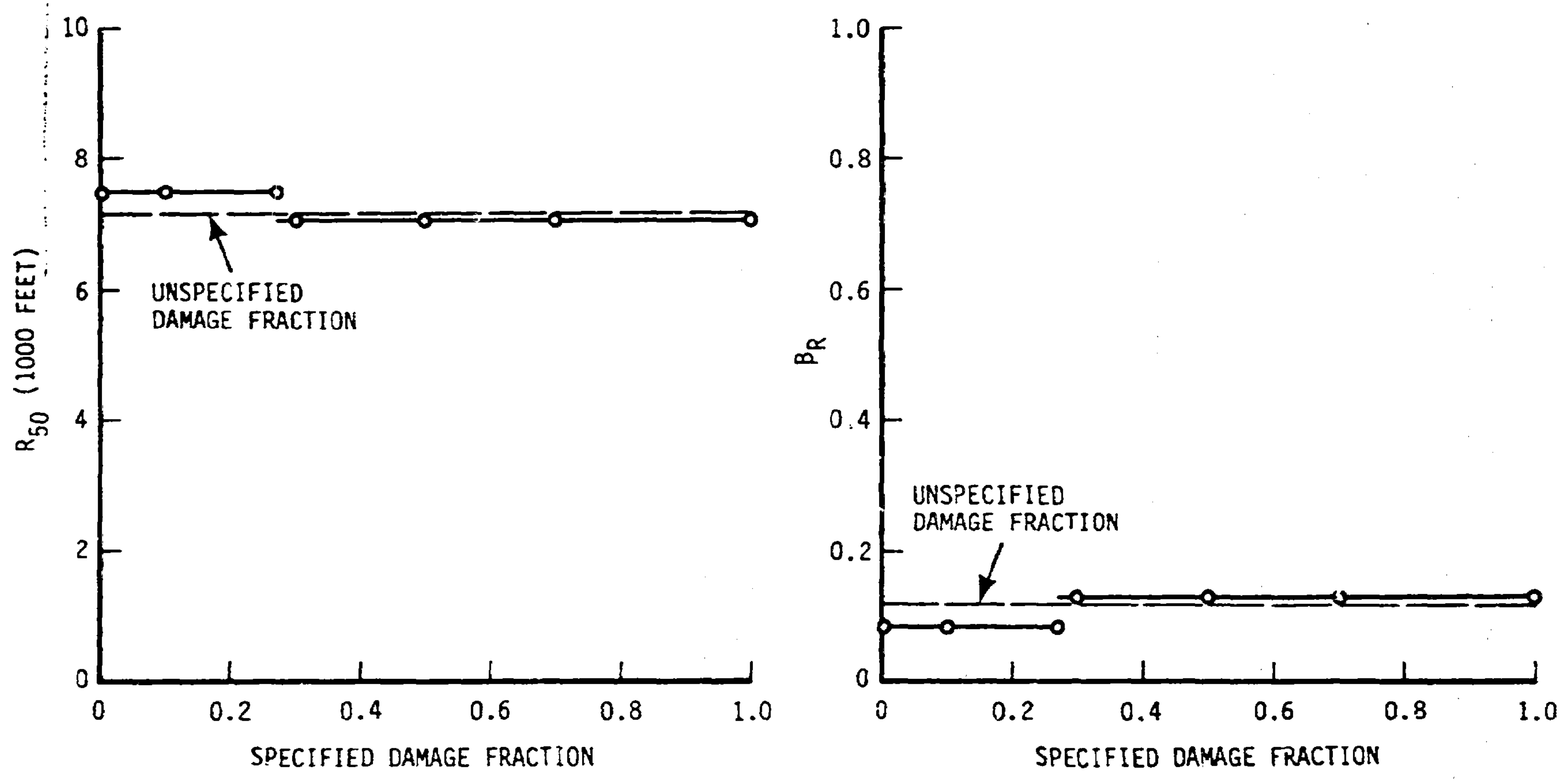


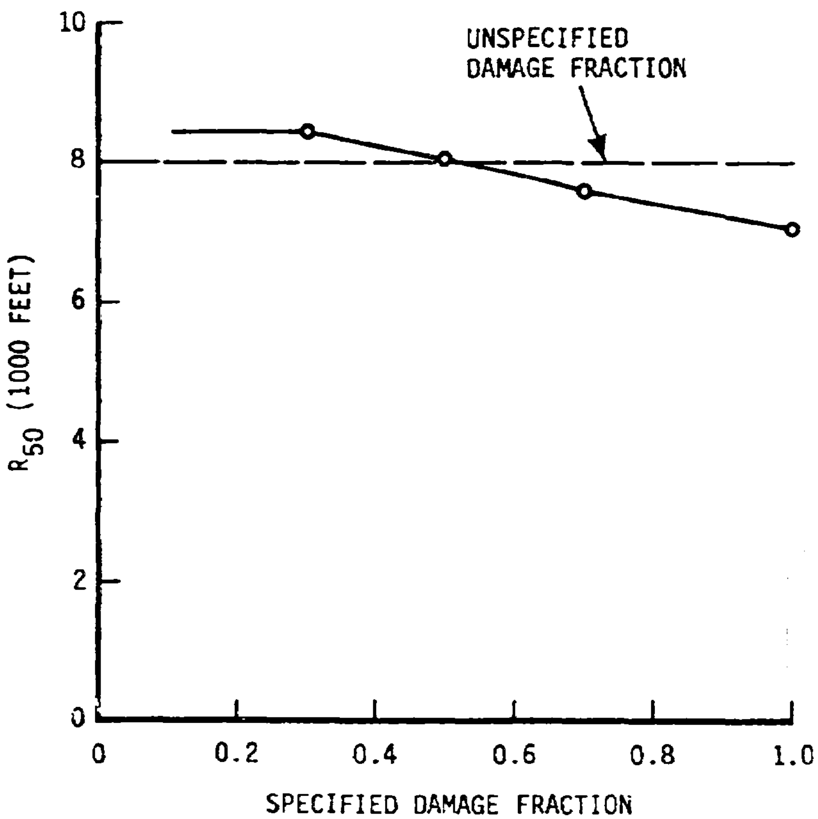
FIGURE 10d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

MASCNRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

WALL THICKNESS OF 7 TO 14 INCHES

STRUCTURAL DAMAGE TO WALLS



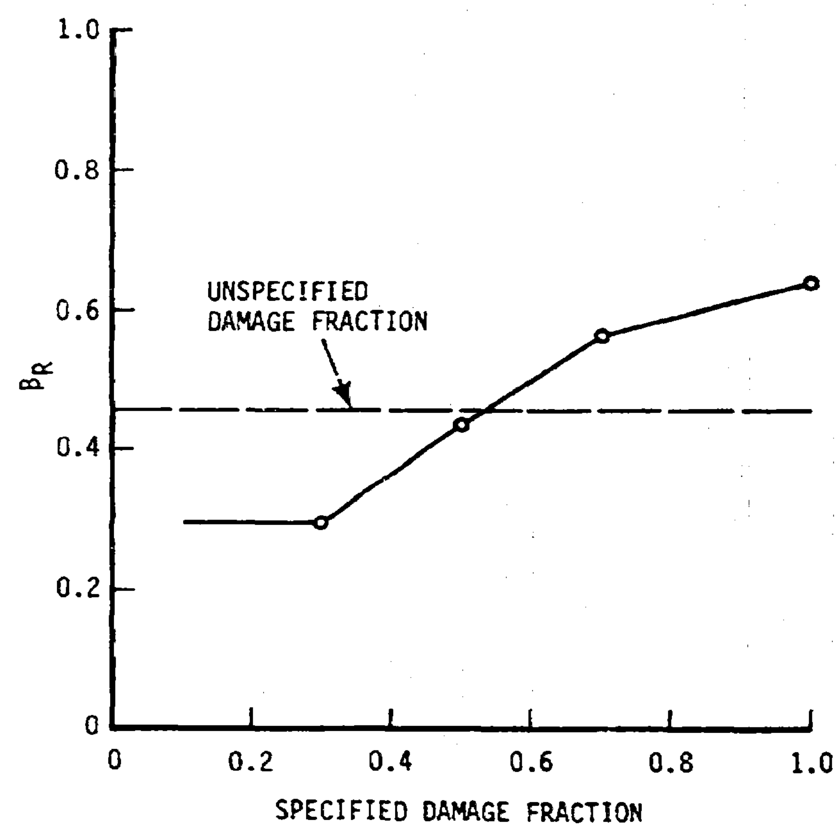


FIGURE 10e

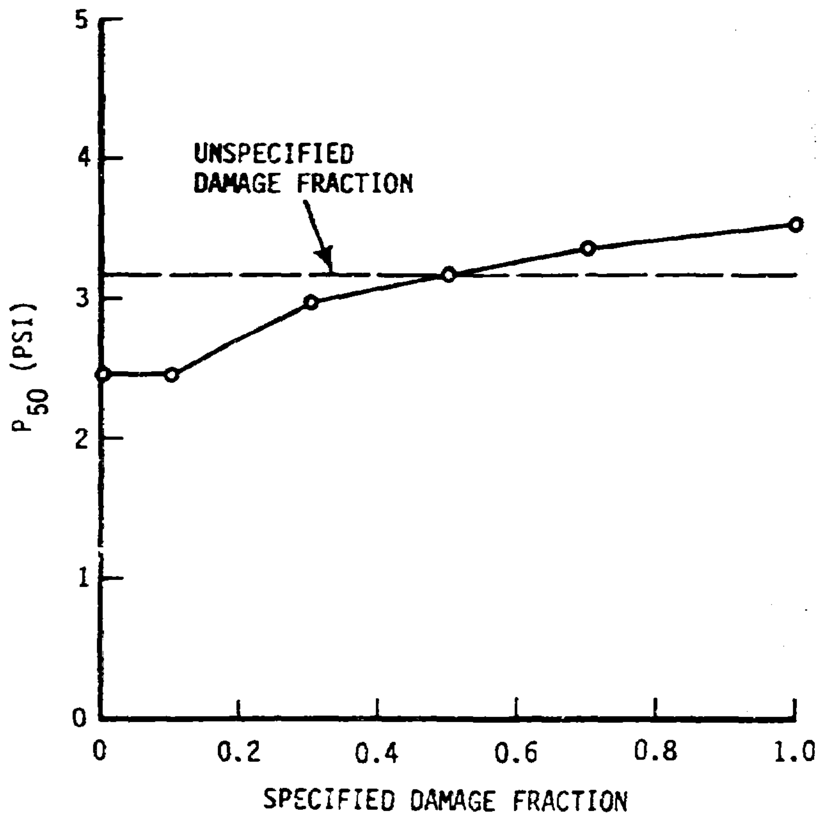
EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

MASONRY LOAD-BEARING-WALL BUILDINGS

WALL THICKNESS OF 7 TO 14 INCHES

STRUCTURAL DAMAGE TO WALLS

HIROSHIMA YIELD ASSUMED = 12 KT



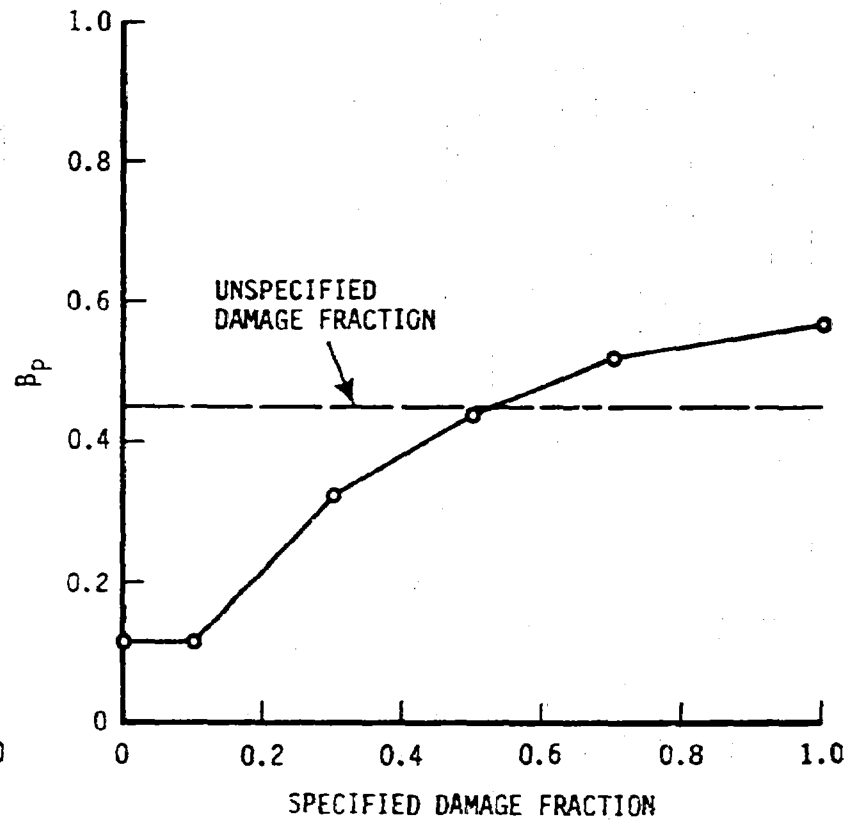


FIGURE 10f

CONFIDENCE REGIONS FOR P_{50} AND β_p

MASONRY LOAD-BEARING-WALL BUILDINGS

WALL THICKNESS OF 7 TO 14 INCHES

STRUCTURAL DAMAGE TO WALLS

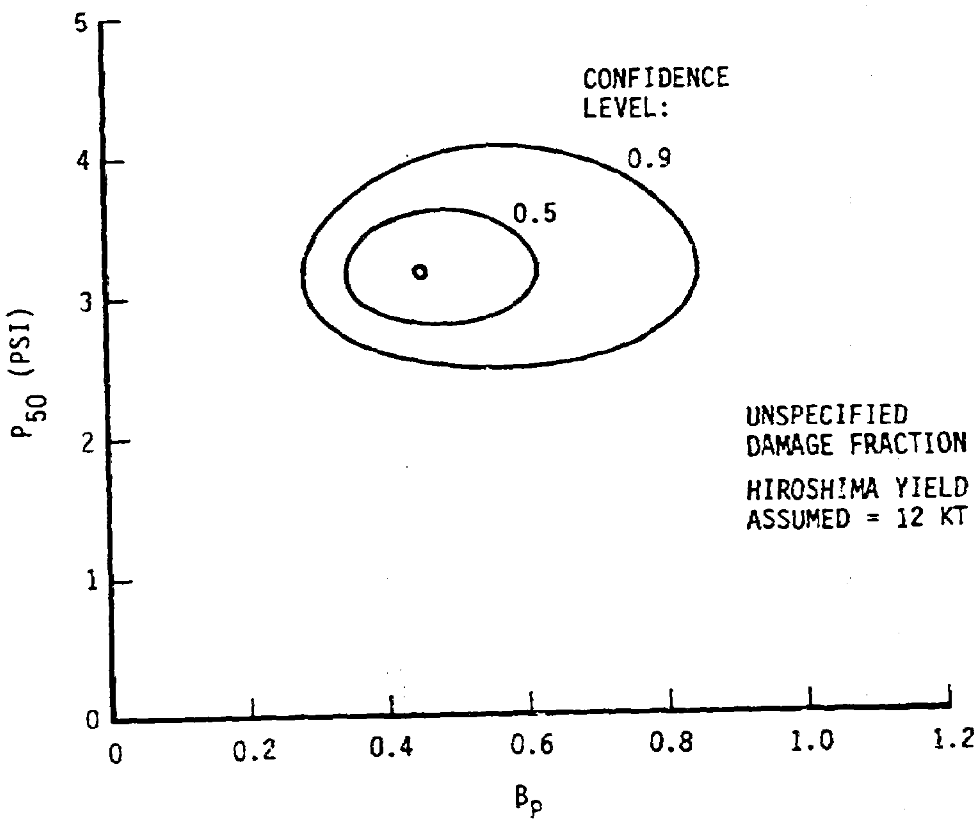


FIGURE 10g

CONFIDENCE REGIONS FOR R_{50} AND β_R

MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
WALL THICKNESS OF 7 TO 14 INCHES
STRUCTURAL DAMAGE TO WALLS

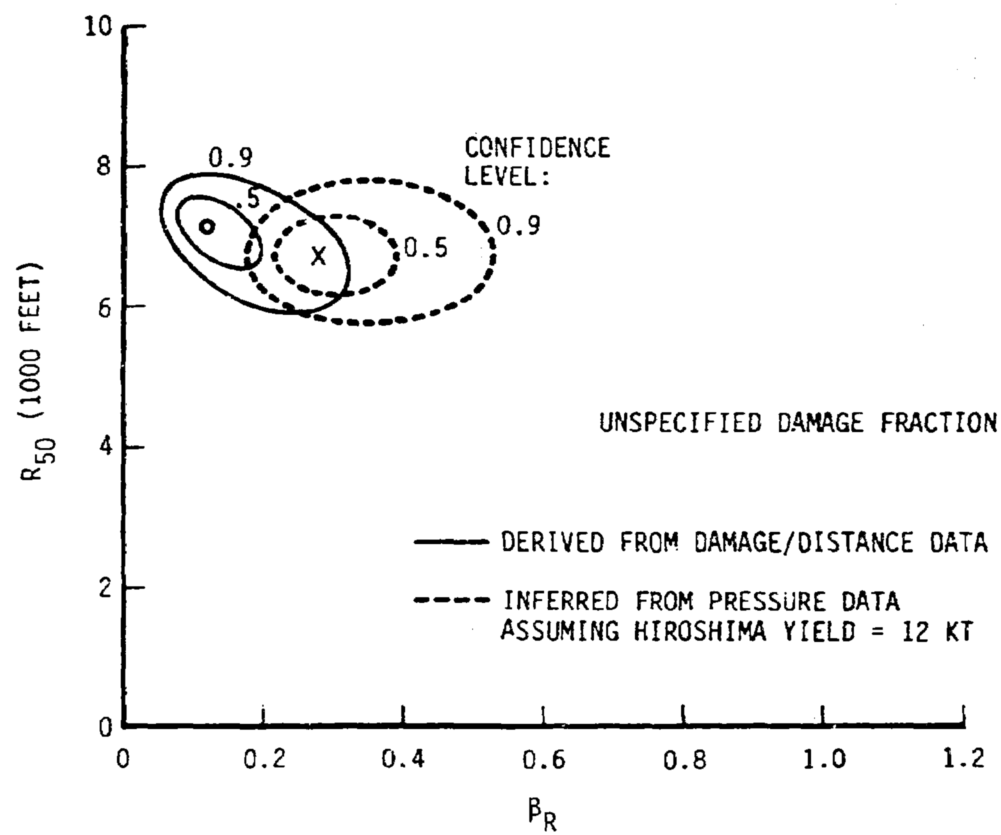


FIGURE 10h

CONFIDENCE REGIONS FOR R_{50} AND β_R

MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

WALL THICKNESS OF 7 TO 14 INCHES

STRUCTURAL DAMAGE TO WALLS

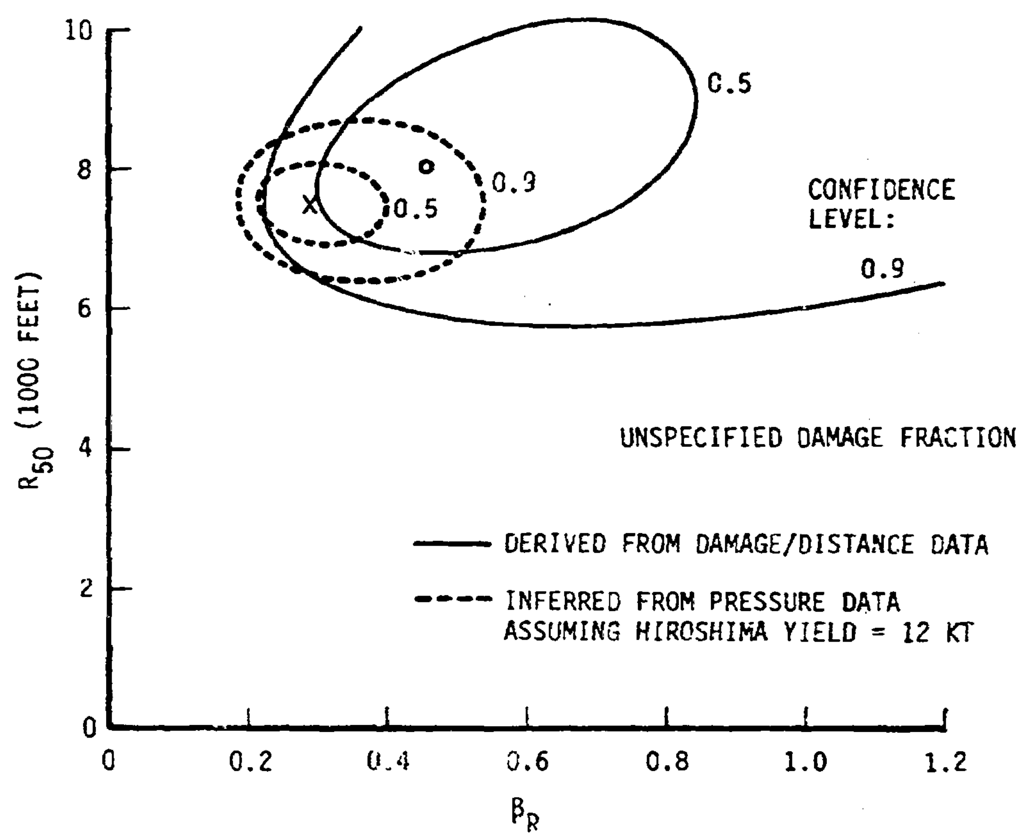


FIGURE 11a

DAMAGE VERSUS DISTANCE DATA

MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
WALL THICKNESS OF 17 TO 27 INCHES
STRUCTURAL DAMAGE TO WALLS

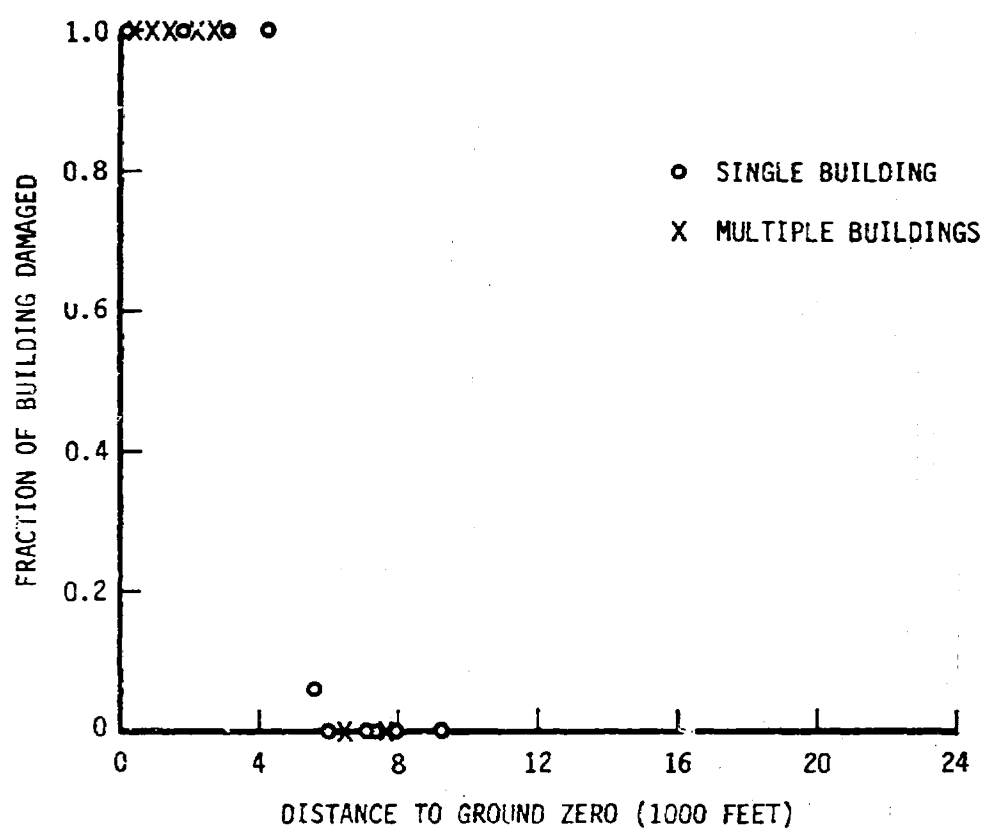


FIGURE 11b

DAMAGE VERSUS DISTANCE DATA

MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI
WALL THICKNESS OF 17 TO 27 INCHES
STRUCTURAL DAMAGE TO WALLS

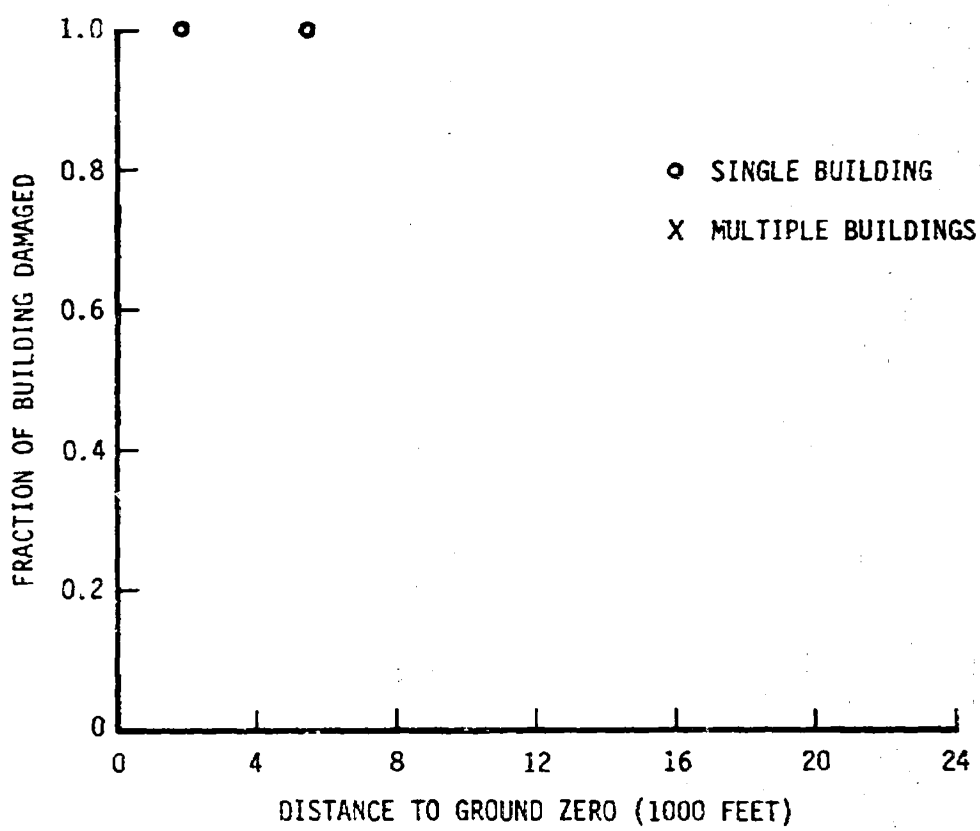


FIGURE 11c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
WALL THICKNESS OF 17 TO 27 INCHES
STRUCTURAL DAMAGE TO WALLS

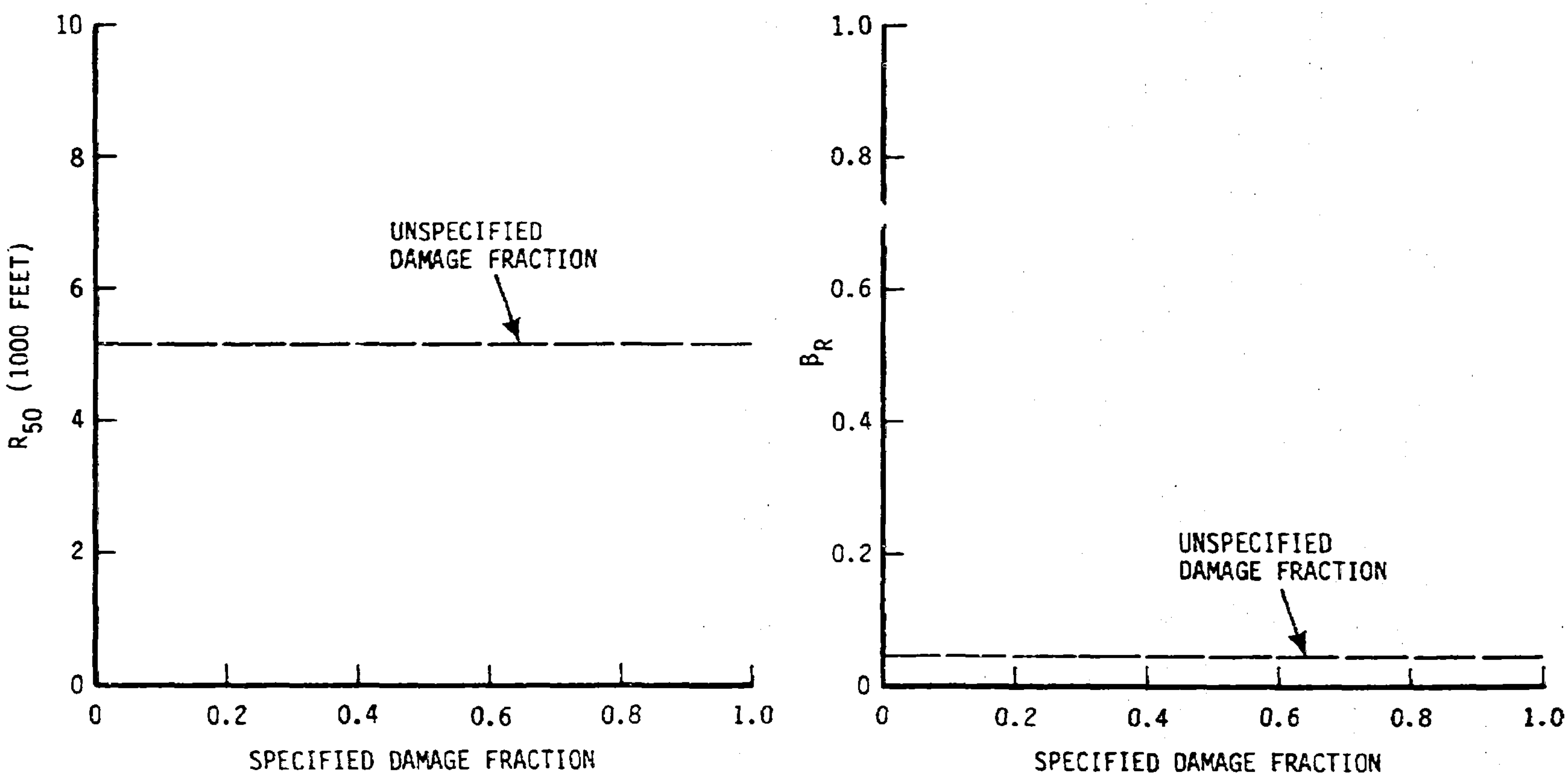


FIGURE 11d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

WALL THICKNESS OF 17 TO 27 INCHES

STRUCTURAL DAMAGE TO WALLS

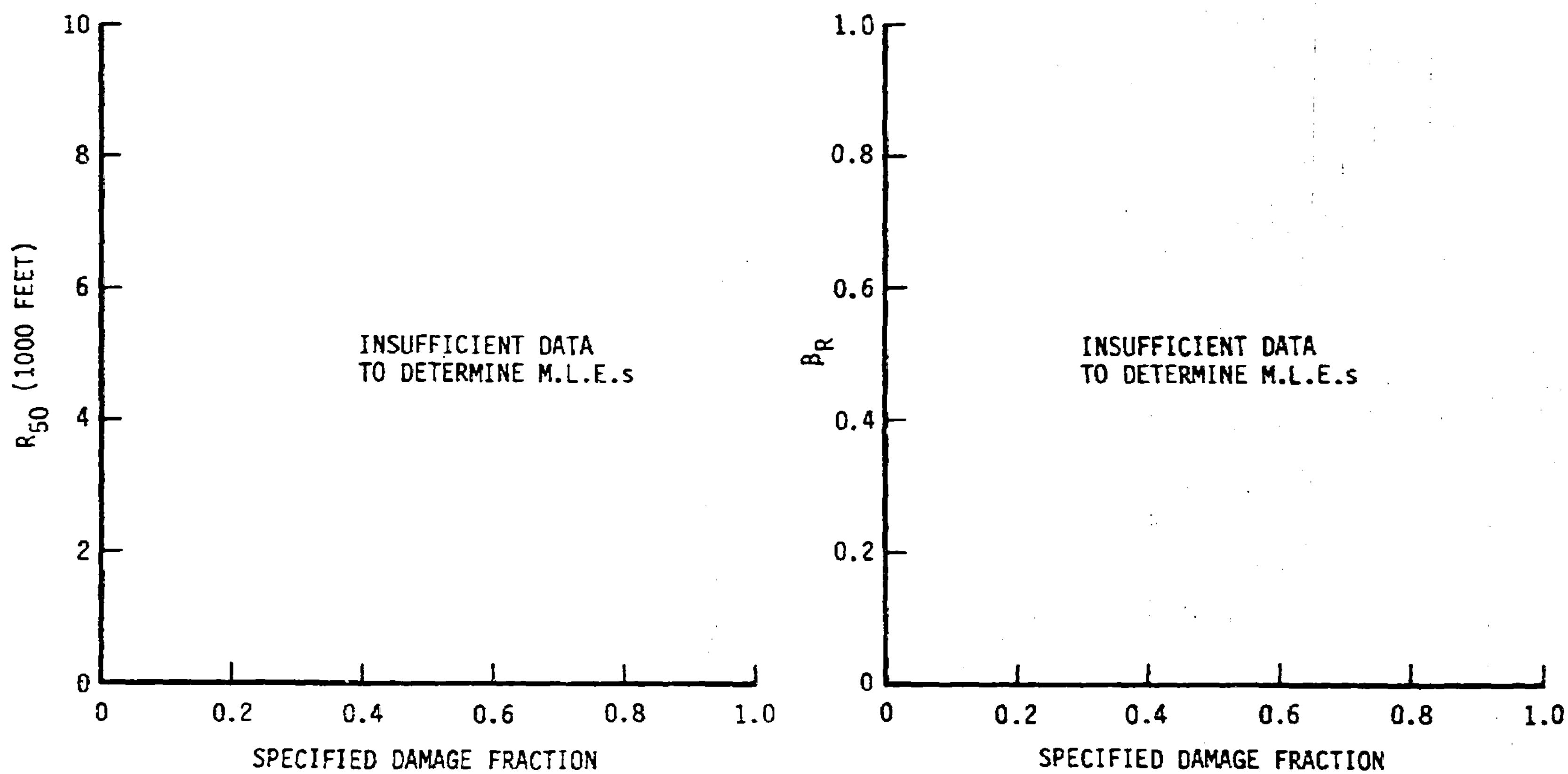
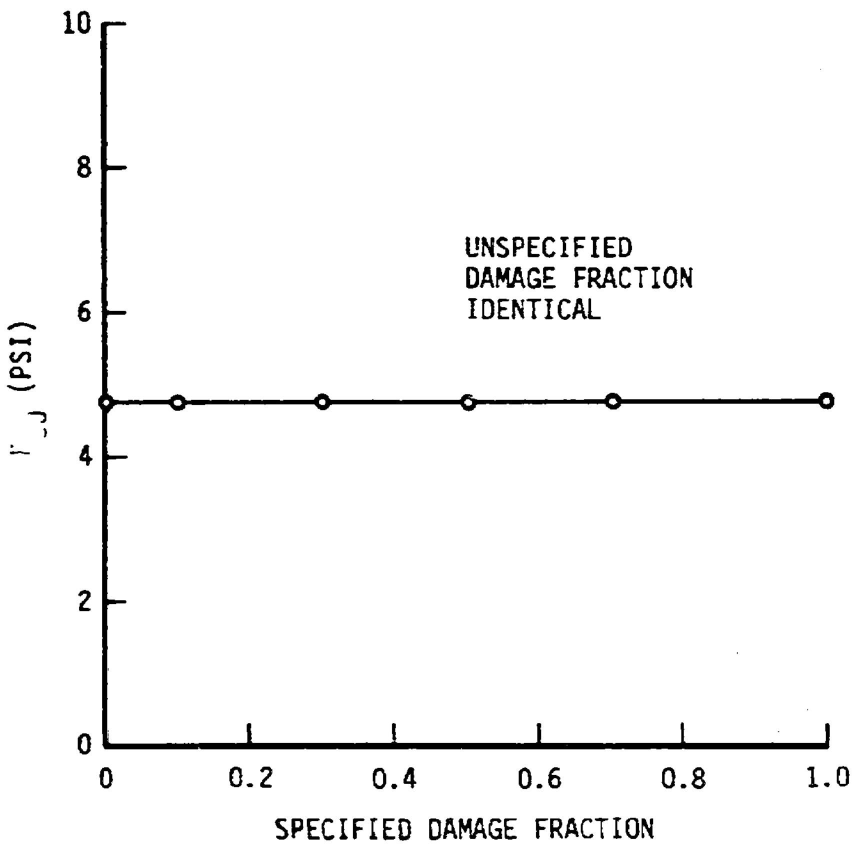


FIGURE 11e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

MASONRY LOAD-BEARING-WALL BUILDINGS
WALL THICKNESS OF 17 TO 27 INCHES
STRUCTURAL DAMAGE TO WALLS

HIROSHIMA YIELD ASSUMED = 12 KT



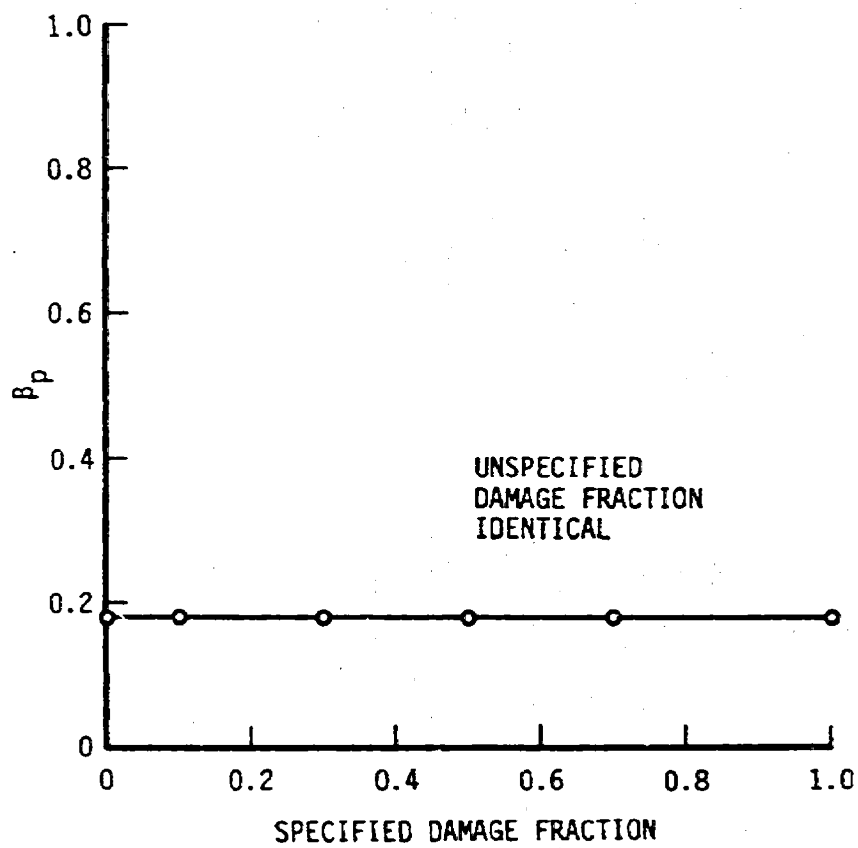


FIGURE 11f

CONFIDENCE REGIONS FOR P_{50} AND β_P

MASONRY LOAD-BEARING-WALL BUILDINGS

WALL THICKNESS OF 17 TO 27 INCHES

STRUCTURAL DAMAGE TO WALLS

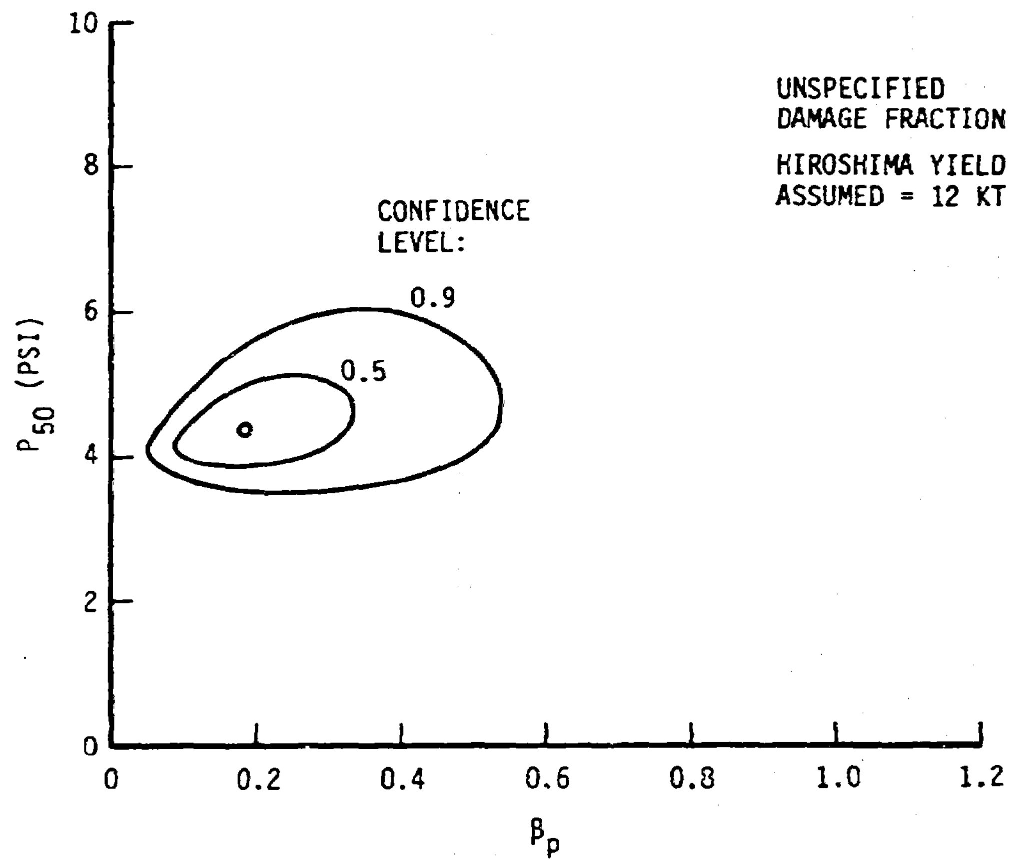


FIGURE 11g

CONFIDENCE REGIONS FOR R_{50} AND β_R

MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
WALL THICKNESS OF 17 TO 27 INCHES
STRUCTURAL DAMAGE TO WALLS

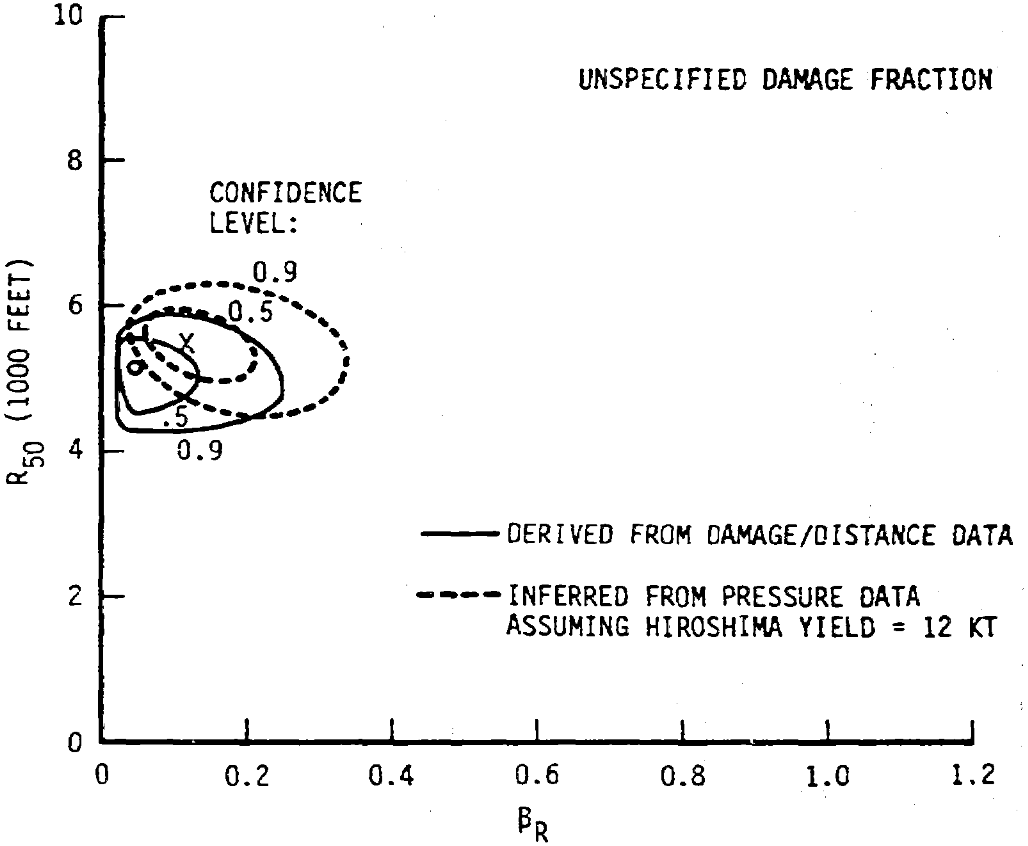


FIGURE 11h

CONFIDENCE REGIONS FOR R_{50} AND β_R

MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI
WALL THICKNESS OF 17 TO 27 INCHES
STRUCTURAL DAMAGE TO WALLS

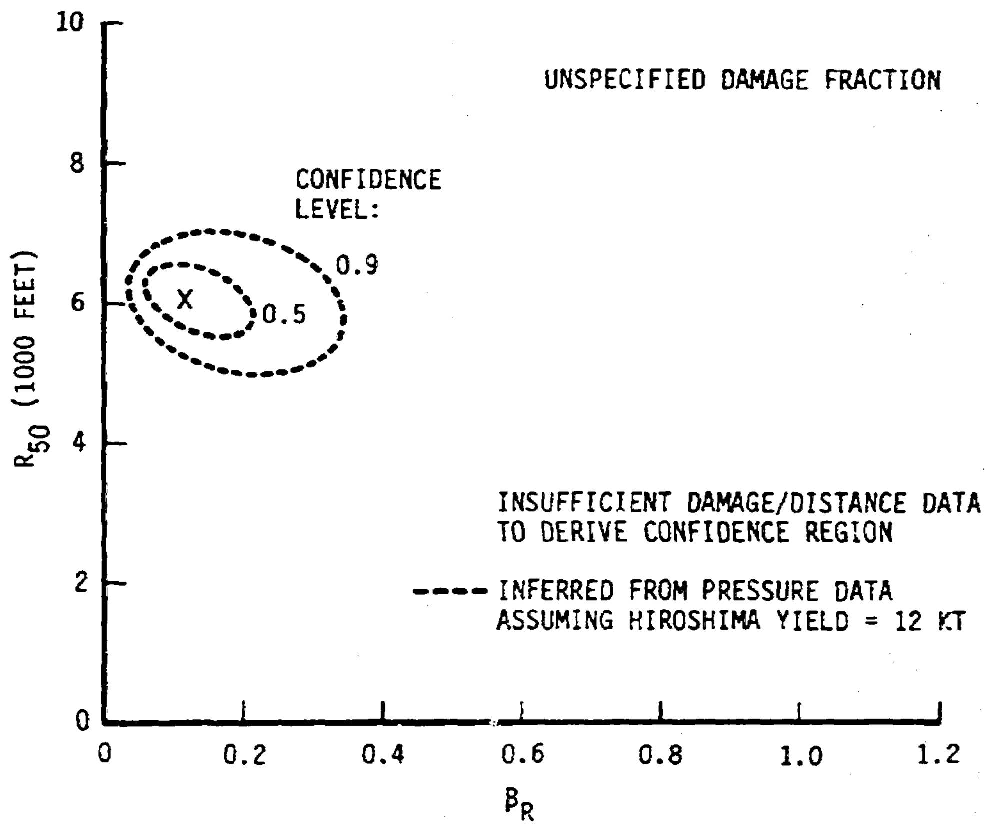


FIGURE 12a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
WALL THICKNESS OF 7 TO 14 INCHES
STRUCTURAL DAMAGE TO WALLS

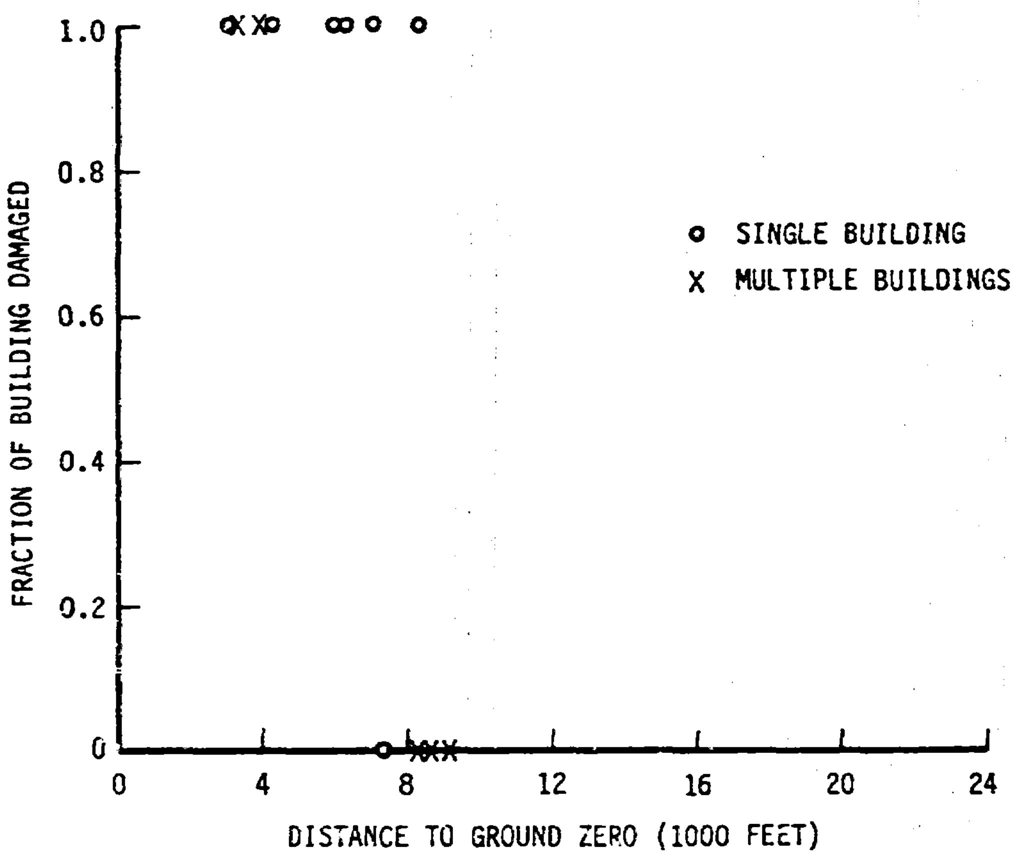


FIGURE 12b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI
WALL THICKNESS OF 7 TO 14 INCHES
STRUCTURAL DAMAGE TO WALLS

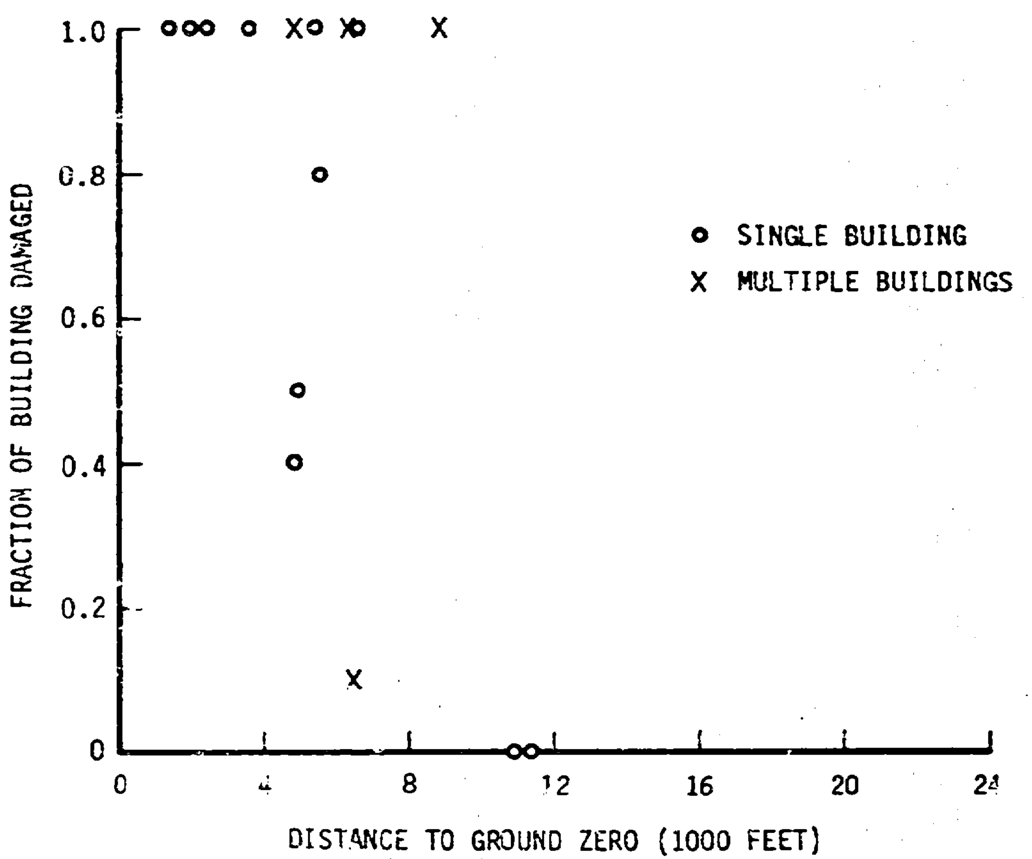


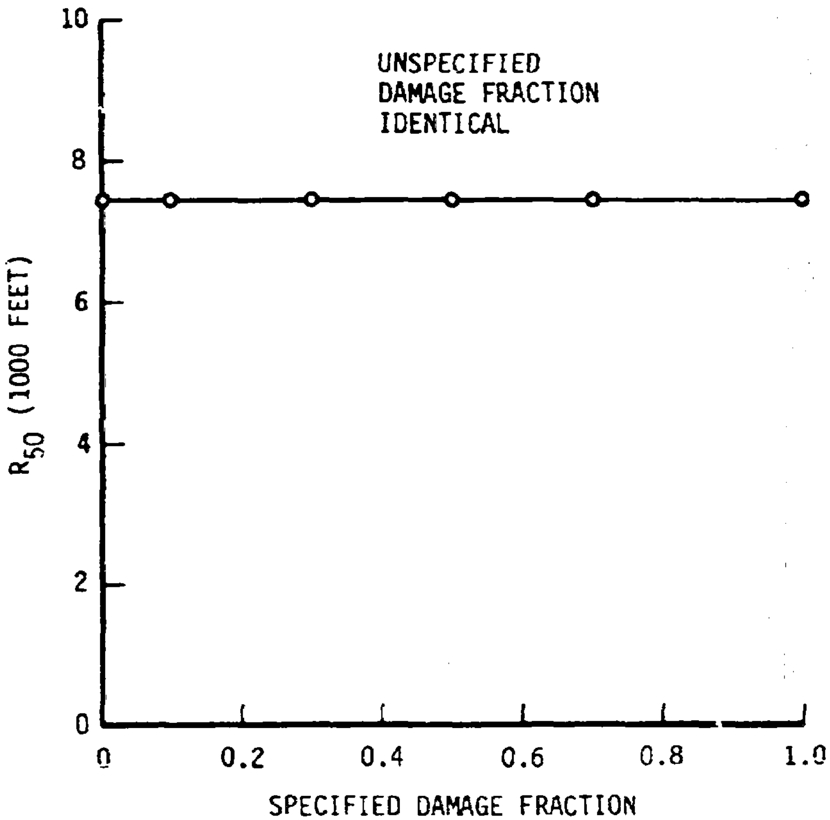
FIGURE 12c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

WALL THICKNESS OF 7 TO 14 INCHES

STRUCTURAL DAMAGE TO WALLS



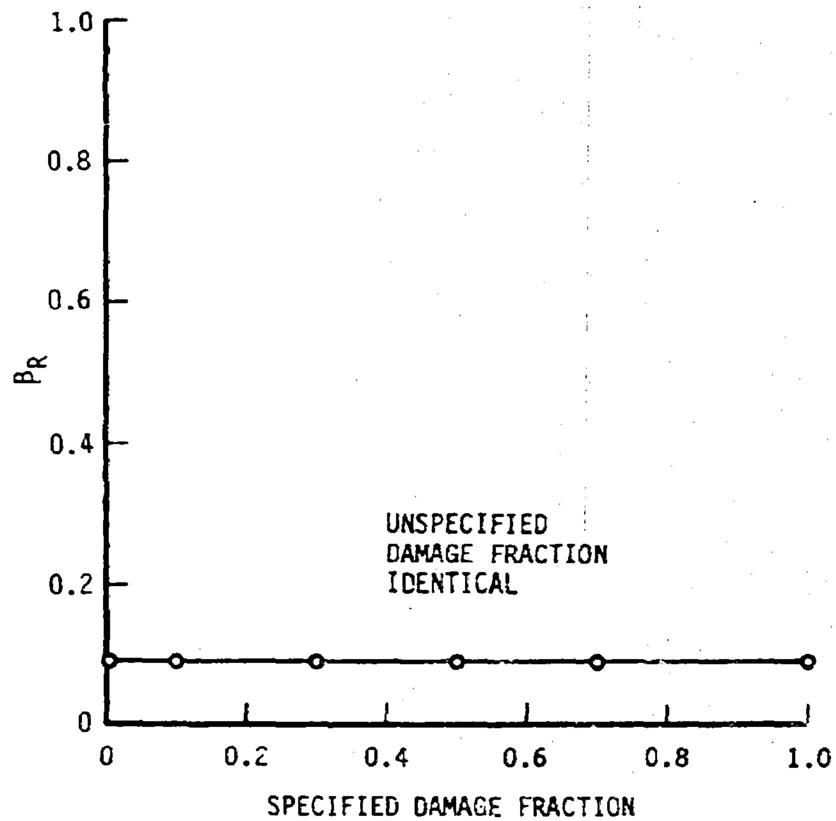


FIGURE 12d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

WALL THICKNESS OF 7 TO 14 INCHES

STRUCTURAL DAMAGE TO WALLS

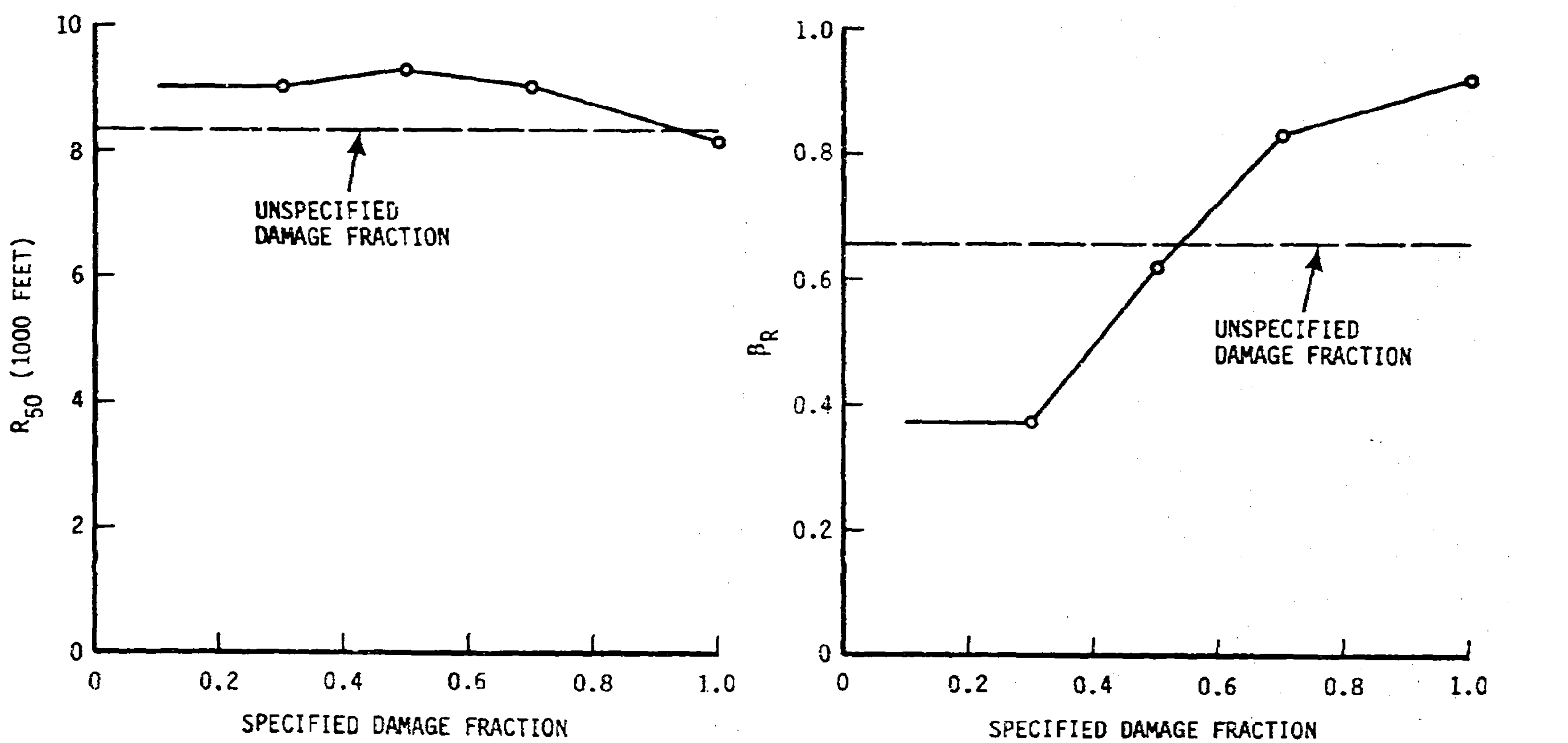


FIGURE 12e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

WALL THICKNESS OF 7 TO 14 INCHES

STRUCTURAL DAMAGE TO WALLS

HIROSHIMA YIELD ASSUMED = 12 KT

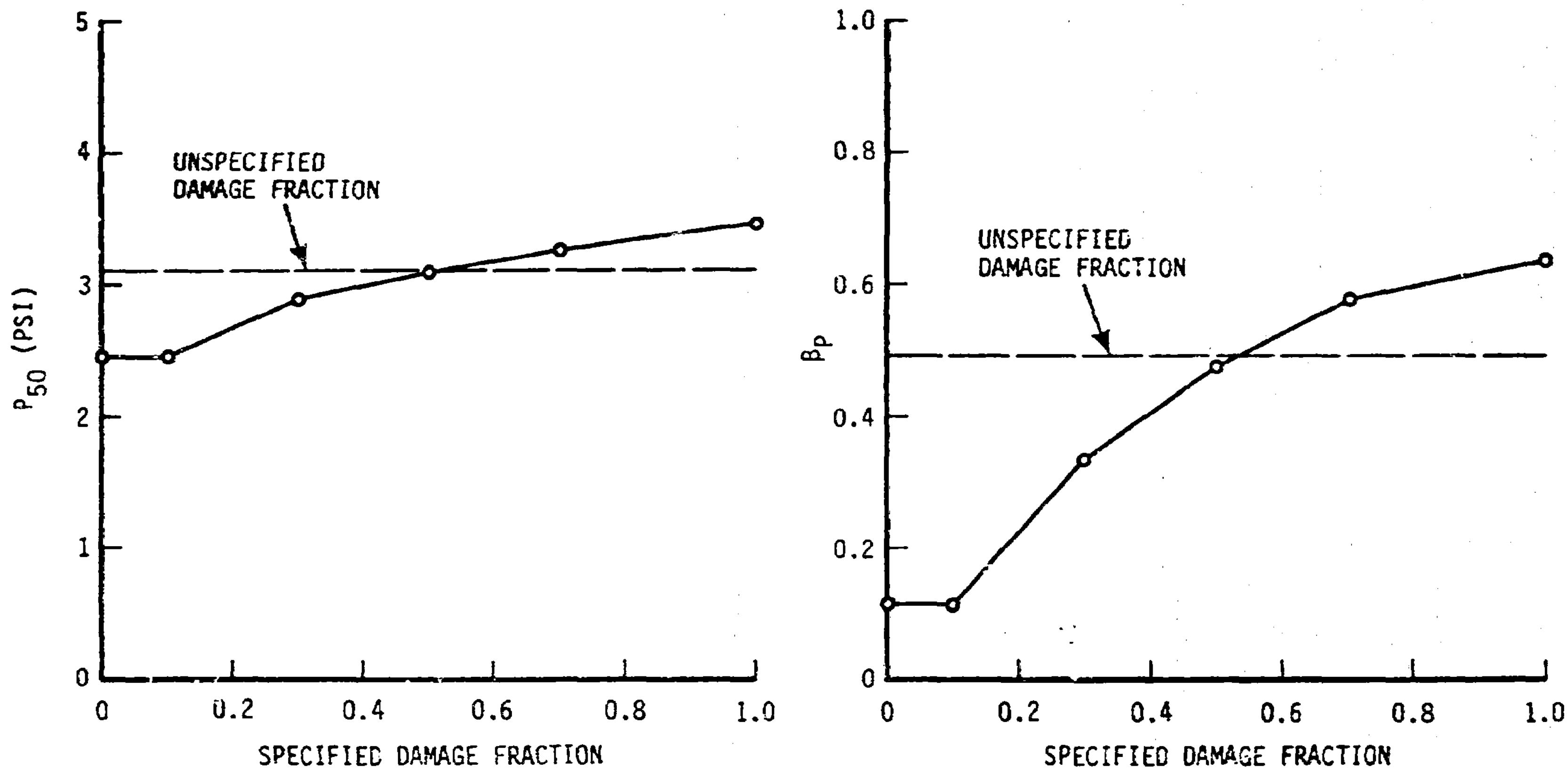


FIGURE 12f

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

WALL THICKNESS OF 7 TO 14 INCHES

STRUCTURAL DAMAGE TO WALLS

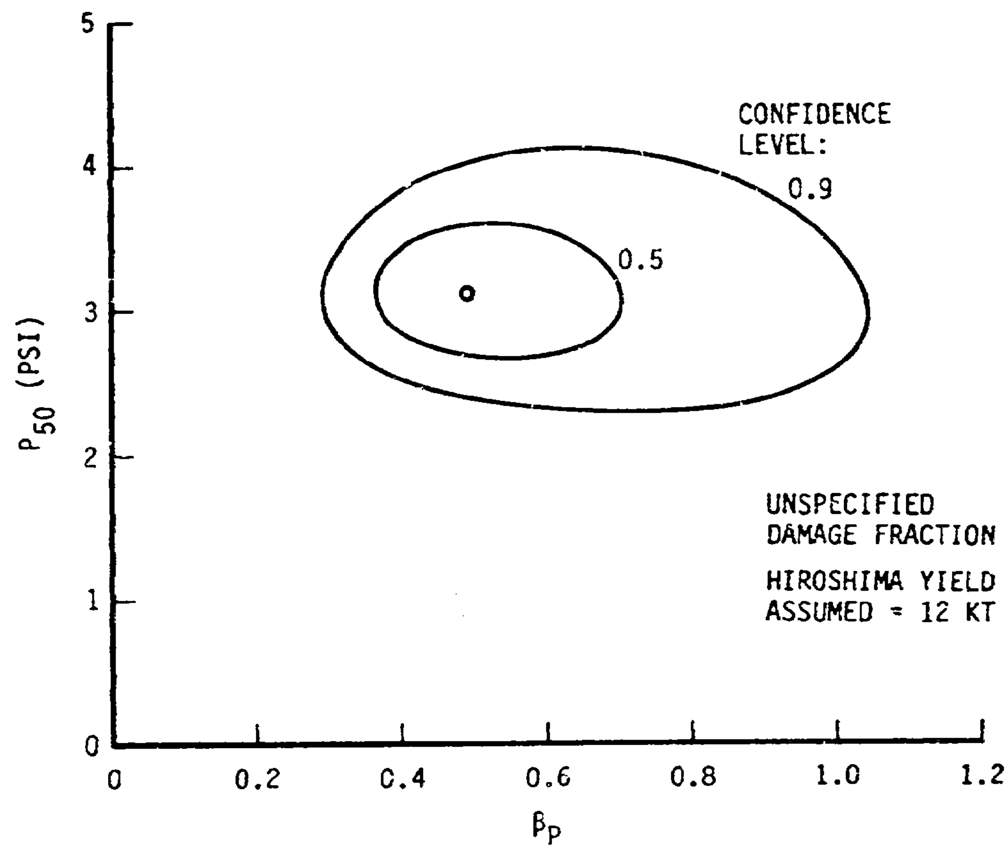


FIGURE 12g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD BEARING-WALL BUILDINGS AT HIROSHIMA

WALL THICKNESS OF 7 TO 14 INCHES

STRUCTURAL DAMAGE TO WALLS

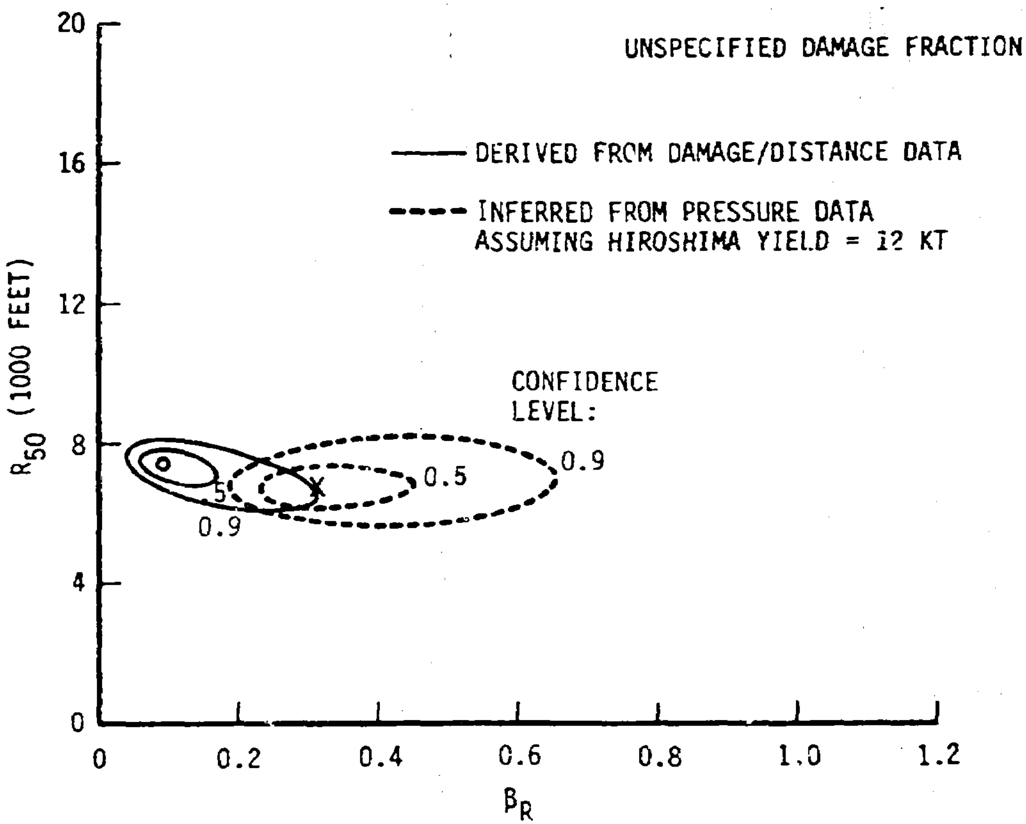


FIGURE 12h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI
WALL THICKNESS OF 7 TO 14 INCHES
STRUCTURAL DAMAGE TO WALLS

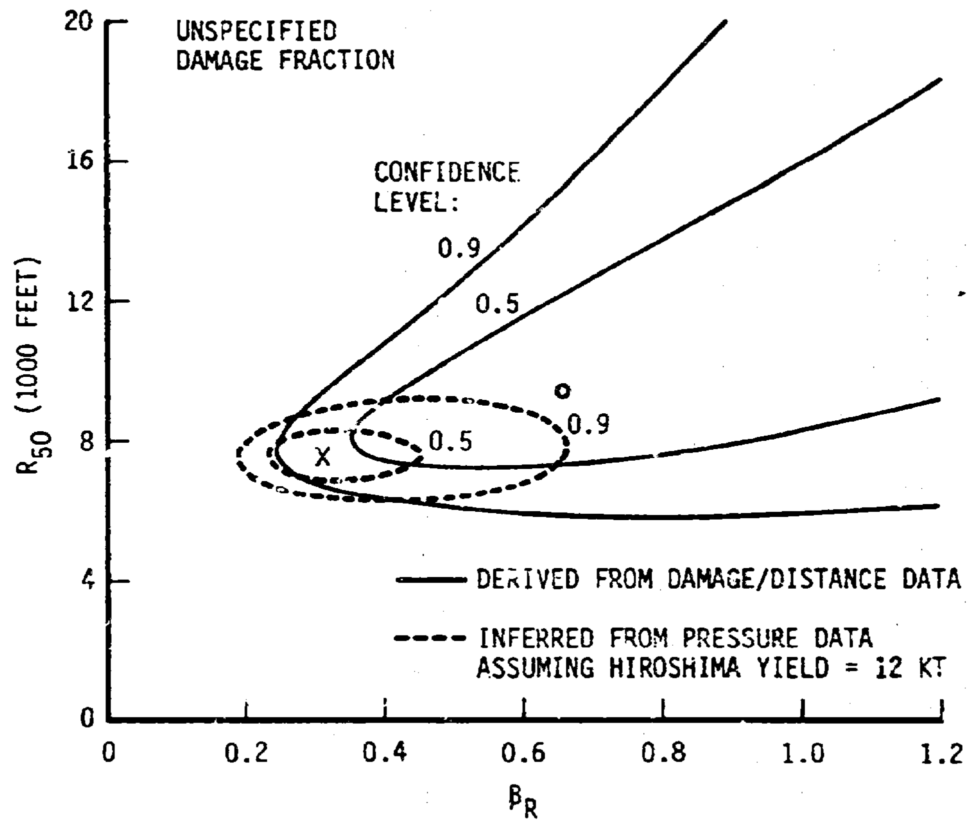


FIGURE 13a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA
WALL THICKNESS OF 17 TO 27 INCHES
STRUCTURAL DAMAGE TO WALLS

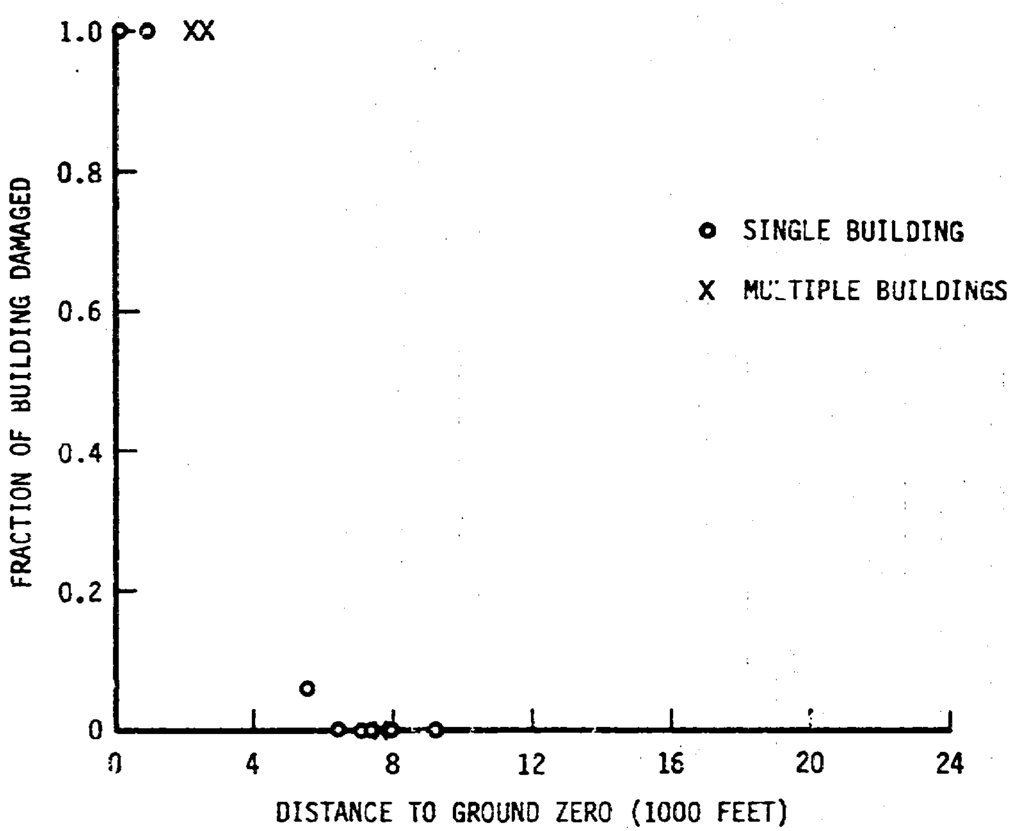


FIGURE 13b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI
WALL THICKNESS OF 17 TO 27 INCHES
STRUCTURAL DAMAGE TO WALLS

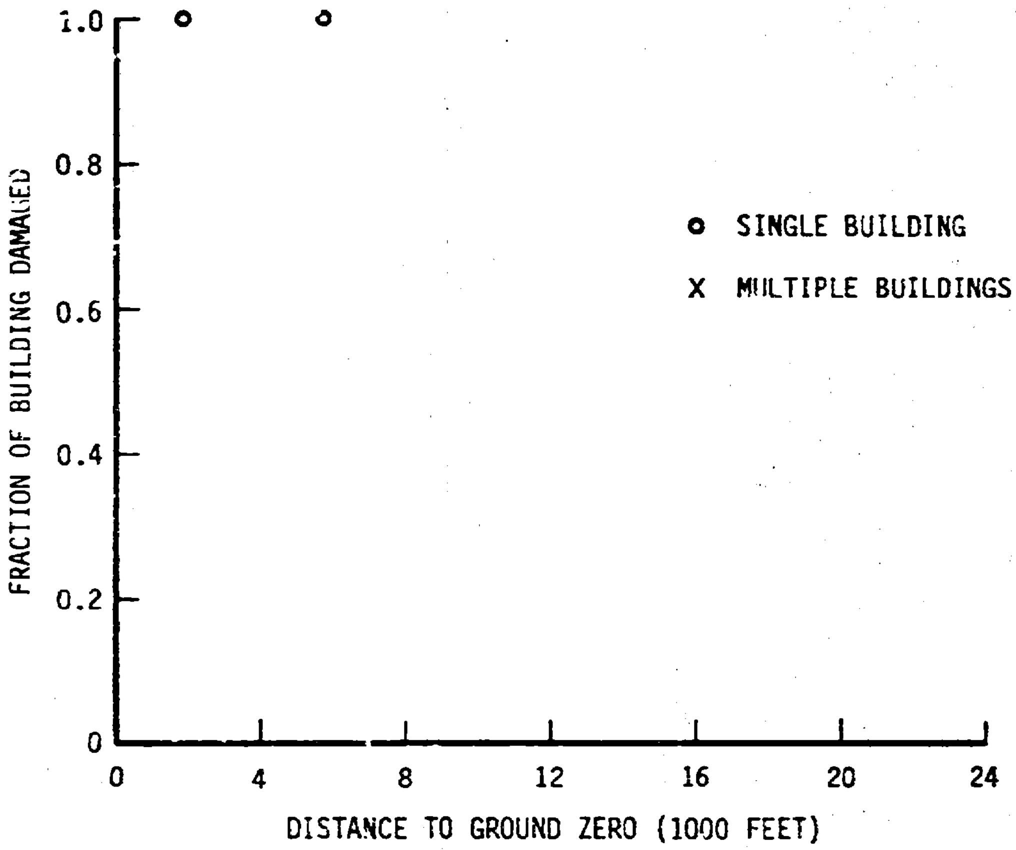


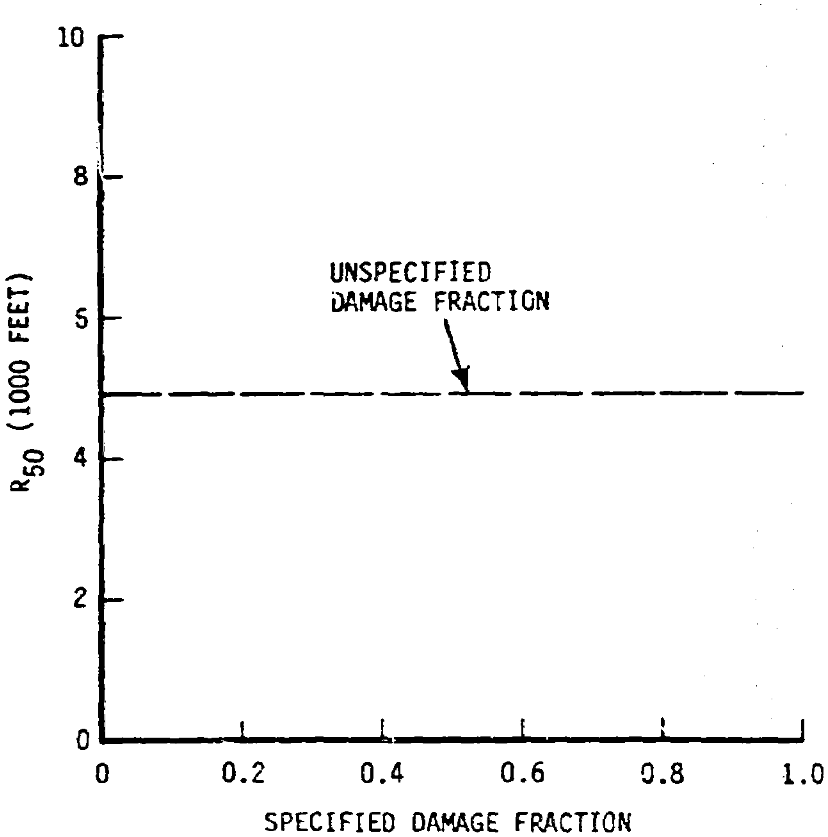
FIGURE 13c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

WALL THICKNESS OF 17 TO 27 INCHES

STRUCTURAL DAMAGE TO WALLS



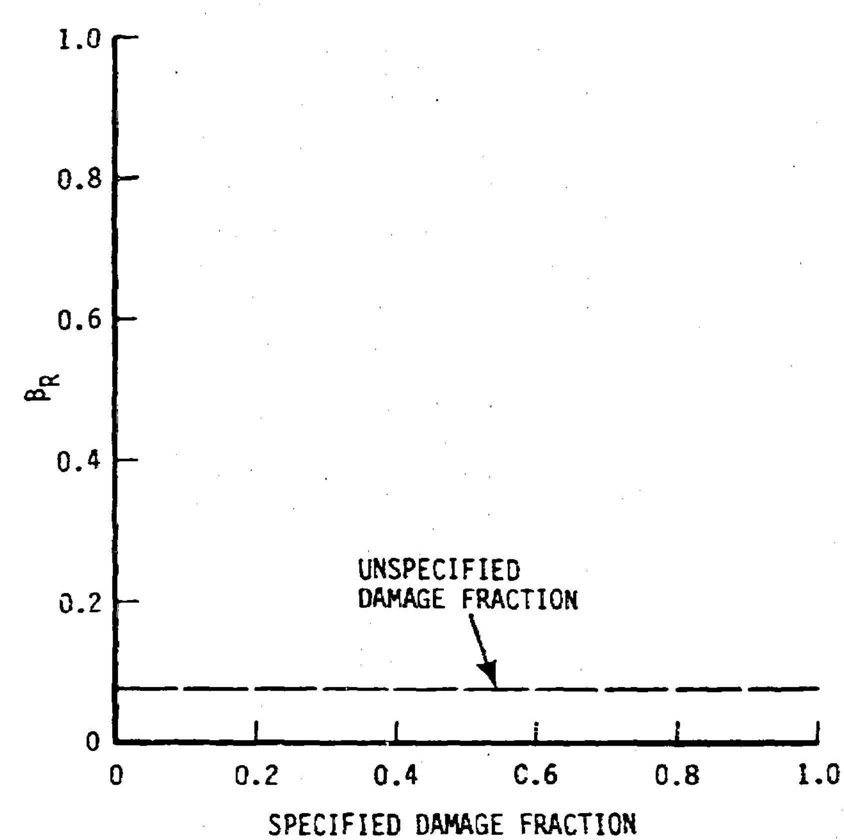


FIGURE 13d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

WALL THICKNESS OF 17 TO 27 INCHES

STRUCTURAL DAMAGE TO WALLS

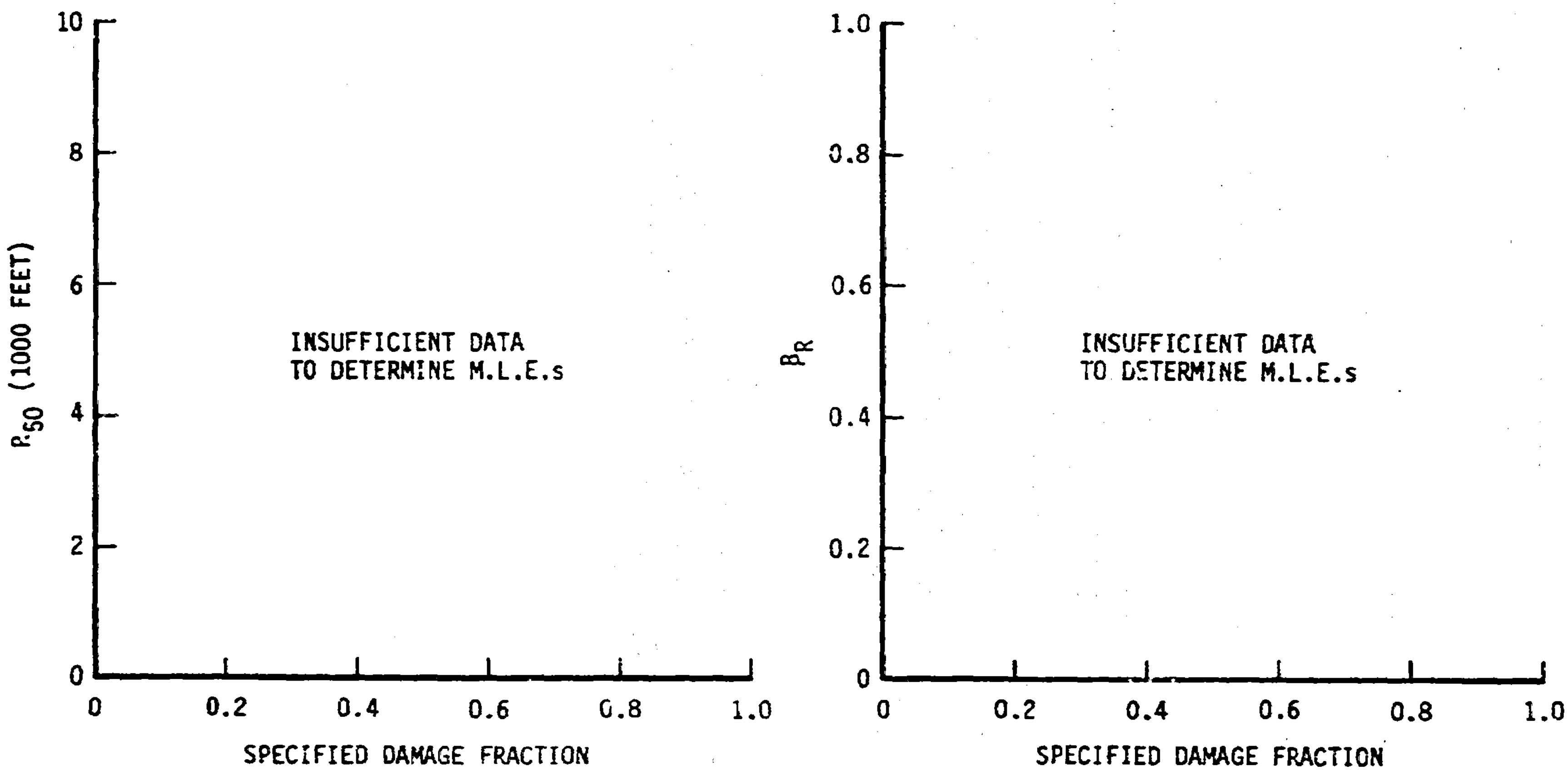


FIGURE 13e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS
WALL THICKNESS OF 17 TO 27 INCHES
STRUCTURAL DAMAGE TO WALLS

HIROSHIMA YIELD ASSUMED = 12 KT

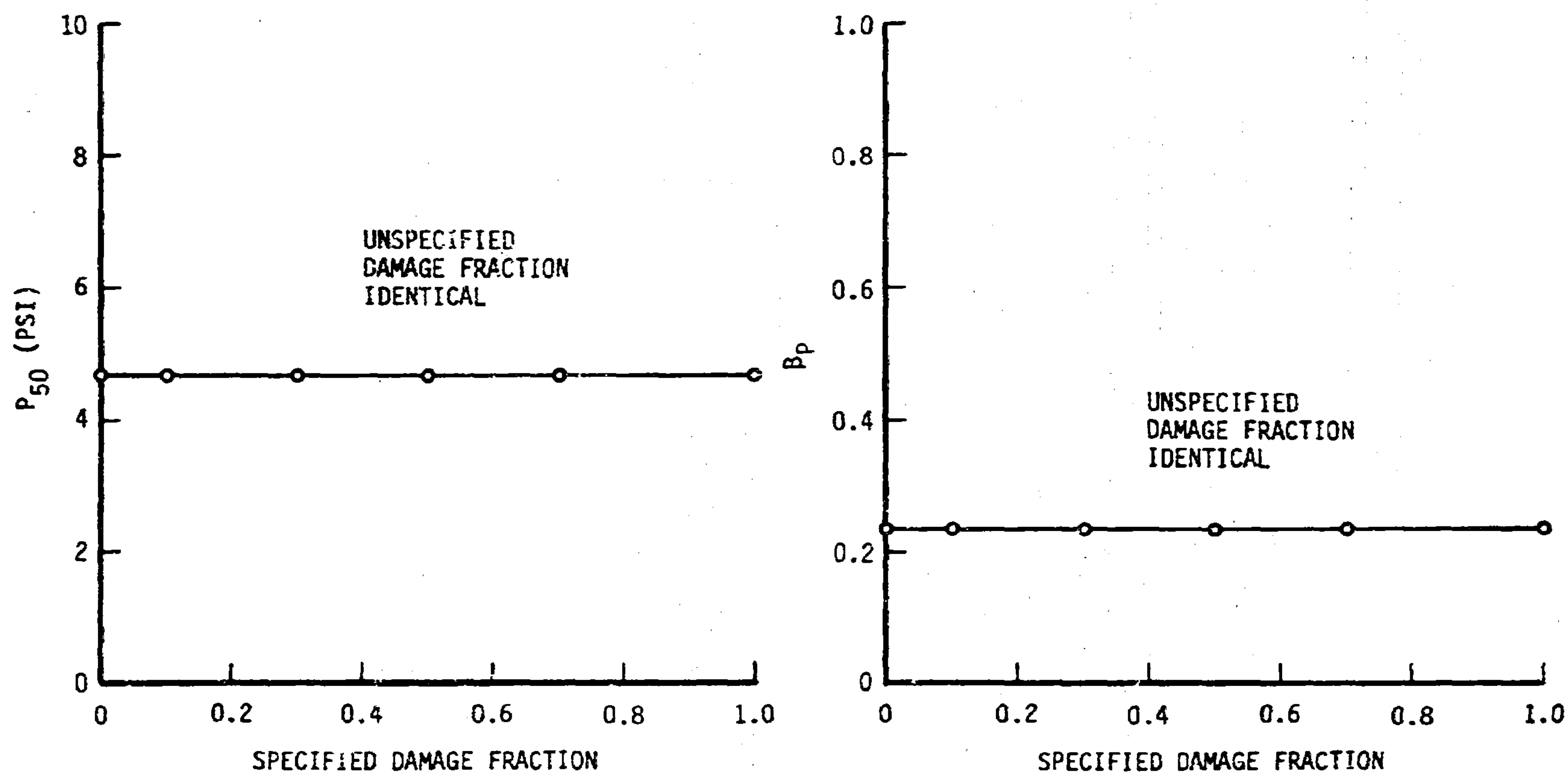


FIGURE 13f

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS

WALL THICKNESS OF 17 TO 27 INCHES

STRUCTURAL DAMAGE TO WALLS

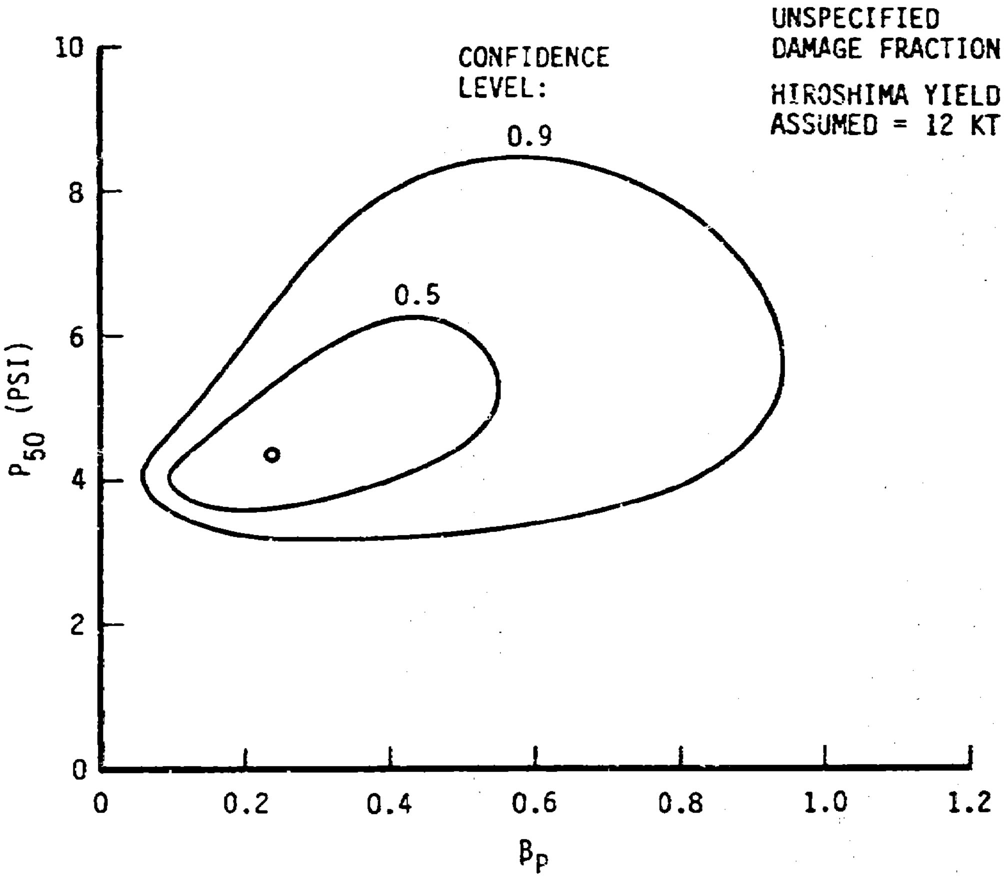


FIGURE 13g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT HIROSHIMA

WALL THICKNESS OF 17 TO 27 INCHES

STRUCTURAL DAMAGE TO WALLS

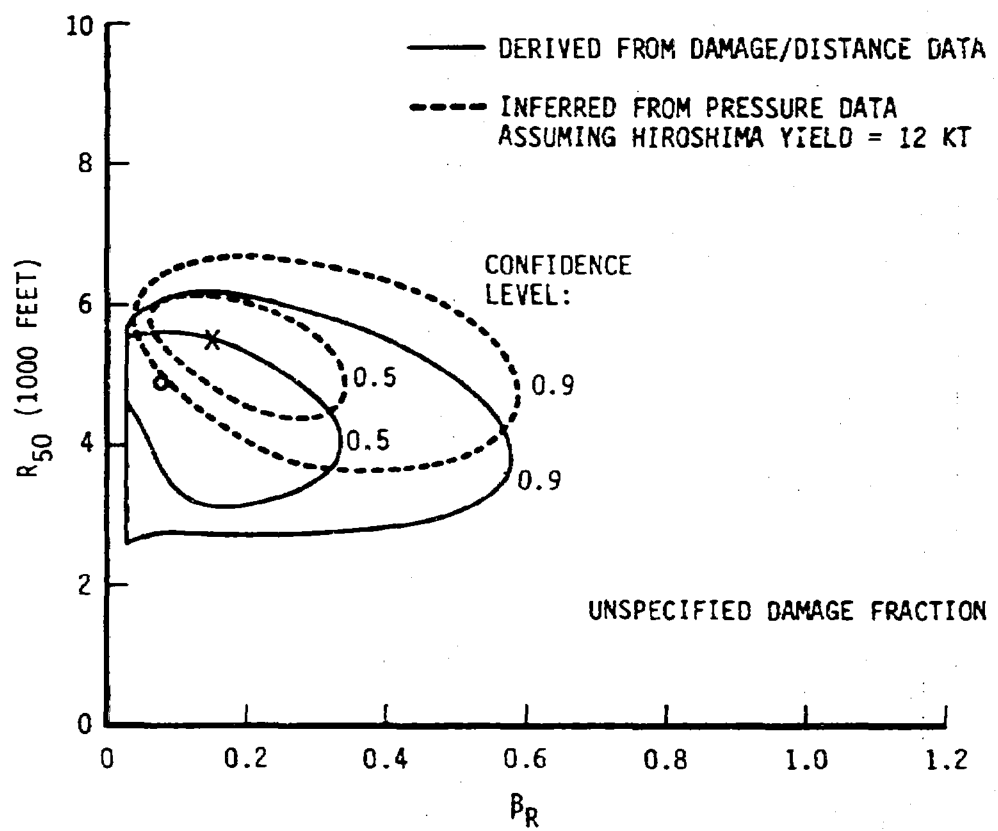


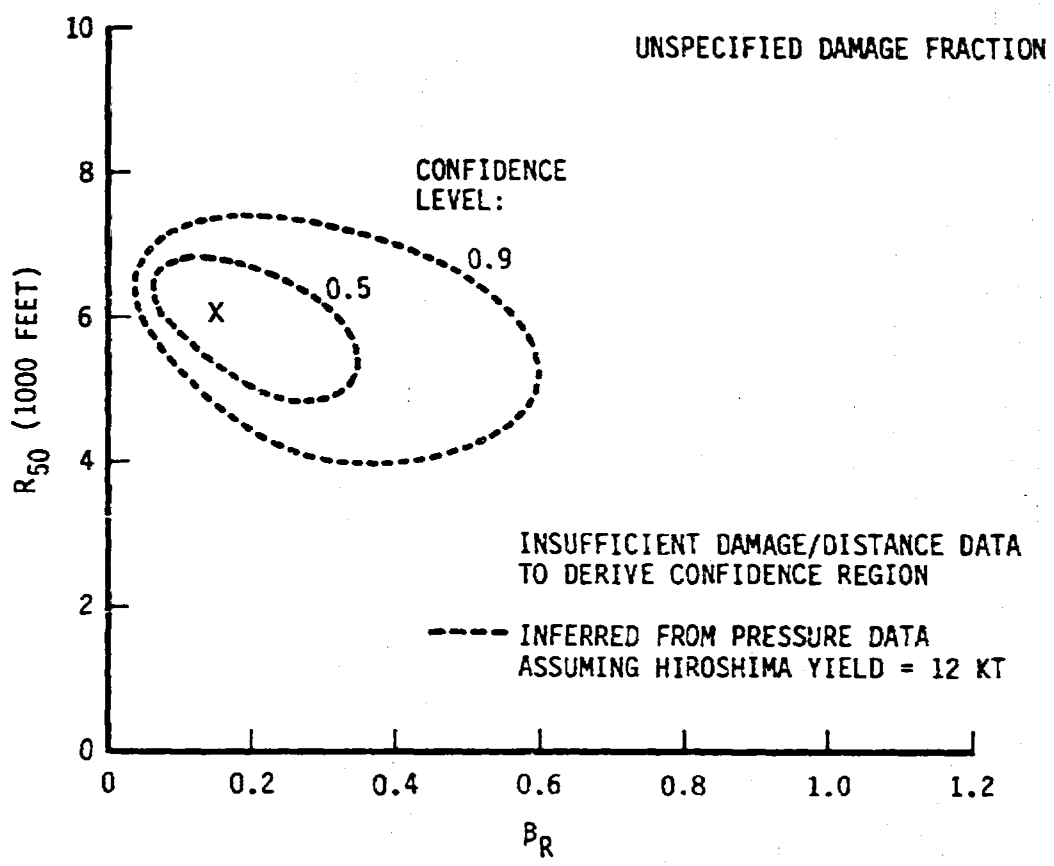
FIGURE 13h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY MASONRY LOAD-BEARING-WALL BUILDINGS AT NAGASAKI

WALL THICKNESS OF 17 TO 27 INCHES

STRUCTURAL DAMAGE TO WALLS



II. WOOD FRAME BUILDINGS

The data base includes 408 Wood Frame Buildings, 103 in Hiroshima and 305 in Nagasaki. The breakdown of the buildings by city, story, and wall type is as follows:

	NUMBER OF BUILDINGS			
WALL TYPE	SINGLE-STORY		MULTISTORY	
	Hiro	Naga	Hiro	Naga
1	75	220	21	38
2	2	12	1	0
5	4	1	0	0
9	0	32	0	2
TOTAL	81	265	22	40

Wall Type 1 (normal wood walls) contains the vast majority of the buildings (87 percent). Wall Type 2 are buildings with quick failing or open walls, and Wall Type 5 contains heavy crane columns for added support. However, there are too few data points to isolate these classes.

The breakdown by roof type is shown in the following table:

	NUMBER OF BUILDINGS			
ROOF TYPE	SINGLE-STORY		MULTISTORY	
	Hiro	Naga	Hiro	Naga
1	0	0	0	0
2	0	1	0	0
3	0	4	0	0
4	61	191	15	31
5	17	17	3	4
9	3	51	4	5
TOTAL	81	265	22	40

As for the Masonry Buildings, the various subclasses of Single-Story Wood Frame Buildings have a fair amount of consistency in the β_p's. Note that this means damage-distance sigmas (σ_d's) of about 32 ± 6.

Although Nagasaki has nearly three times the number of Wood Frame Buildings in comparison to Hiroshima, most of them are too close (or too far) from the ground zero to help the analysis. This is readily apparent from the summary table. Note that the Single-Story Nagasaki subclasses have about 10 percent of the points near the mean (the superficial slow and quick roof types have 5 and 0 percent, respectively). For the same cases, the Hiroshima data have over half the buildings near the mean. This may be one possible explanation of the apparent poor agreement between the confidence limits for the two cities.

Since 70 percent of the Single-Story Buildings have normal wood walls and slow failing wood truss roofs, this subclass has been isolated in the Structural and Superficial cases. The quick failing roof class has also been isolated for Superficial Damage, even though the data base includes only 25 points with 12 within one sigma of the mean. The points were not adequately placed to derive meaningful results for the Structural Damage, however.

The Multistory buildings are examined similarly to the Single-Story, except that there are too few points to look at any subdivision except the normal wood walls and slow failing roof. The results show a significantly lower β_p equivalent to a σ_d of 10 to 13. Part of this may be due to more homogeneity in construction among the Multistory Buildings. For example, referring to the data files themselves, most of the critical data points are School Buildings. No such statement can be made about the Single-Story Buildings, which are of widely assorted types and uses.

Nearly all of the roofs are wooden truss with slow failing roof covering material (usually wooden sheathing under the tile or other roofing). The few buildings with steel truss roofs or wood truss roofs with quick failing roof covering material (typically corrugated asbestos) are insufficient to derive reliable results.

The following table presents the cases examined and some of the key observations as for the Masonry Load-Bearing-Wall Buildings.

SUMMARY OF WOOD FRAME BUILDINGS

TYPE	M.L.E. P_{50}	M.L.E. β_P	MAX. 90% CONF. LIM. P_{50}	MAX. 90% CONF. LIM. β_P	DATA POINTS TOTAL H	DATA POINTS TOTAL N	DATA POINTS ±1 SIGMA H	DATA POINTS ±1 SIGMA N
A. SINGLE-STORY								
1. Structural								
a. All	1.81	.57	1.55-2.10	.43-.71	81	265	52	30
b. Wood, Slow Roof	1.71	.50	1.40-2.05	.35-.75	57	184	36	17
2. Superficial								
a. All	1.47	.43	1.25-1.65	.32-.60	81	265	53	25
b. Wood, Slow Roof	1.46	.41	1.20-1.70	.28-.62	57	184	35	[illegible]
c. Wood, Quick Roof	1.31	.48	<.5 -1.85	.17->1.2	15	10	12	6
3. Structural Roof								
a. Wood Roof	1.82	.63	1.50-2.15	.47-.88	78	208	55	23
B. MULTISTORY								
1. Structural								
a. All	2.37	.17	2.15-2.70	.10-.35	22	40	10	7
b. Wood, Slow Roof	2.41	.19	2.10-2.90	.10-.44	14	31	5	7
2. Superficial								
a. All	2.06	.18	1.83-2.30	.11-.35	22	40	11	7
b. Wood, Slow Roof	2.11	.20	1.80-2.45	.11-.46	14	31	8	7

FIGURE 14a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA
STRUCTURAL DAMAGE CRITERIA

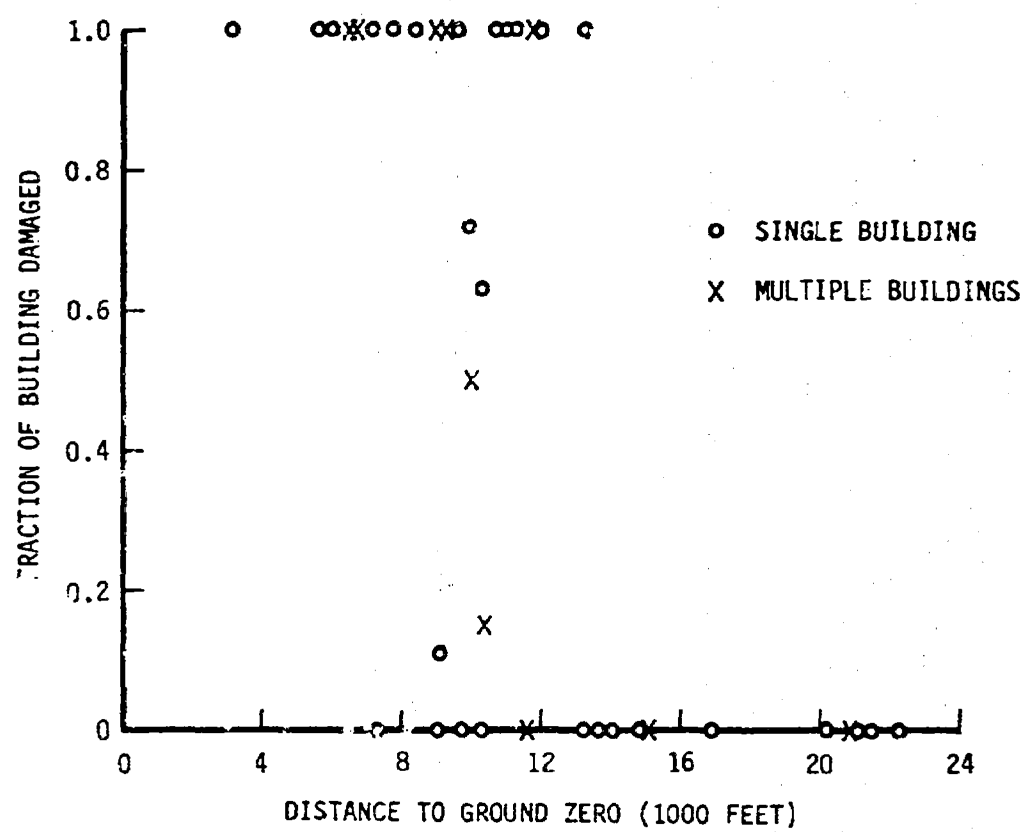


FIGURE 14b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI
STRUCTURAL DAMAGE CRITERIA

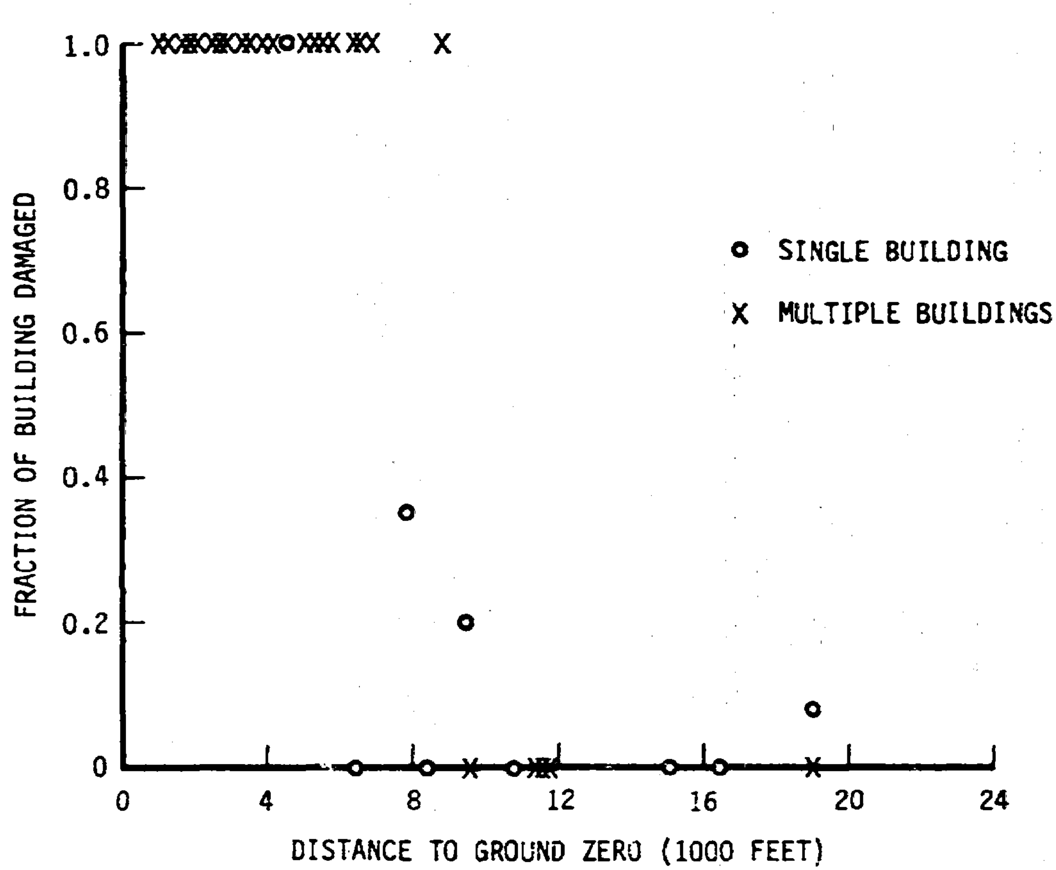


FIGURE 14c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA

STRUCTURAL DAMAGE CRITERIA

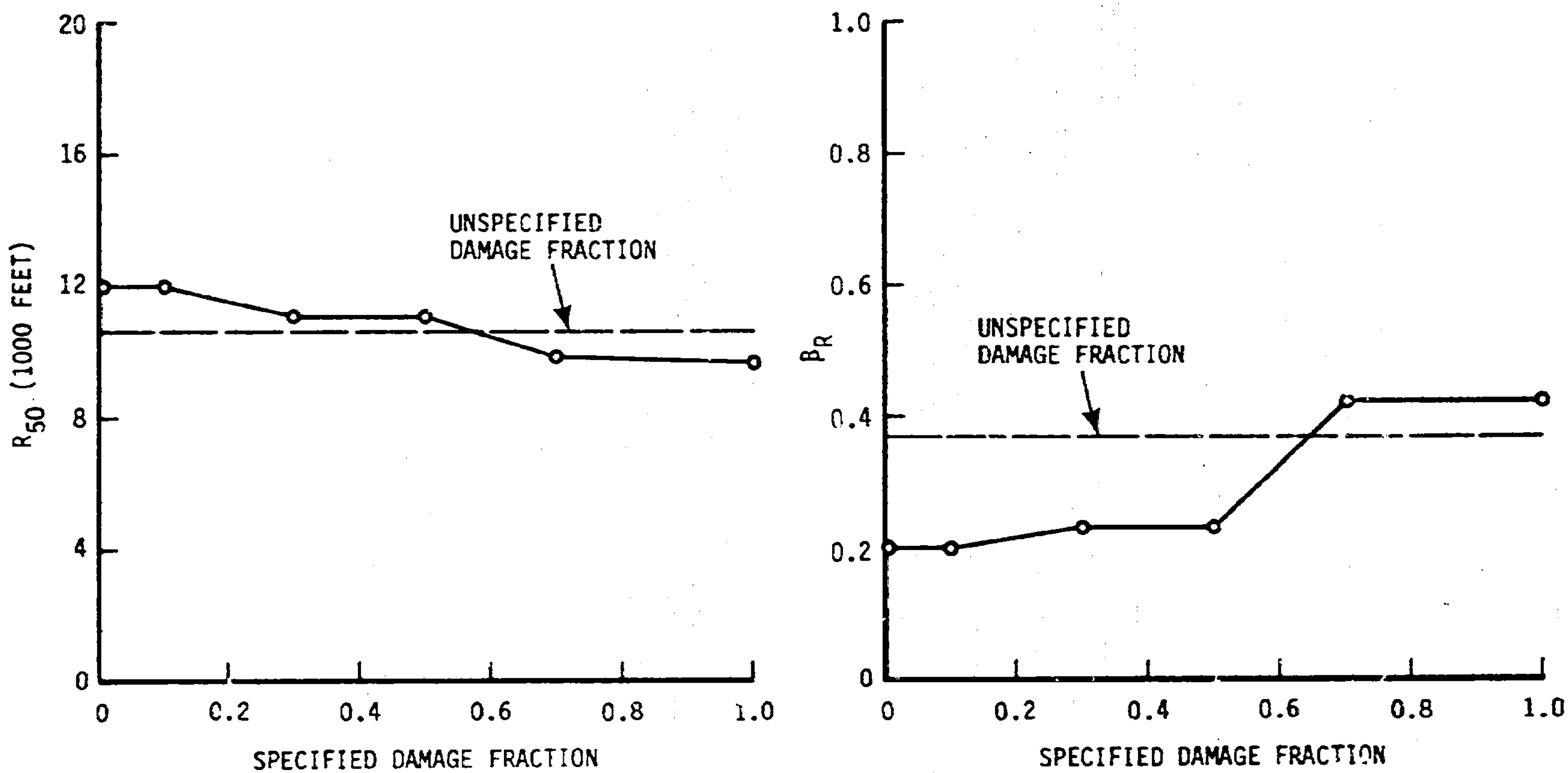


FIGURE 14d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE CRITERIA

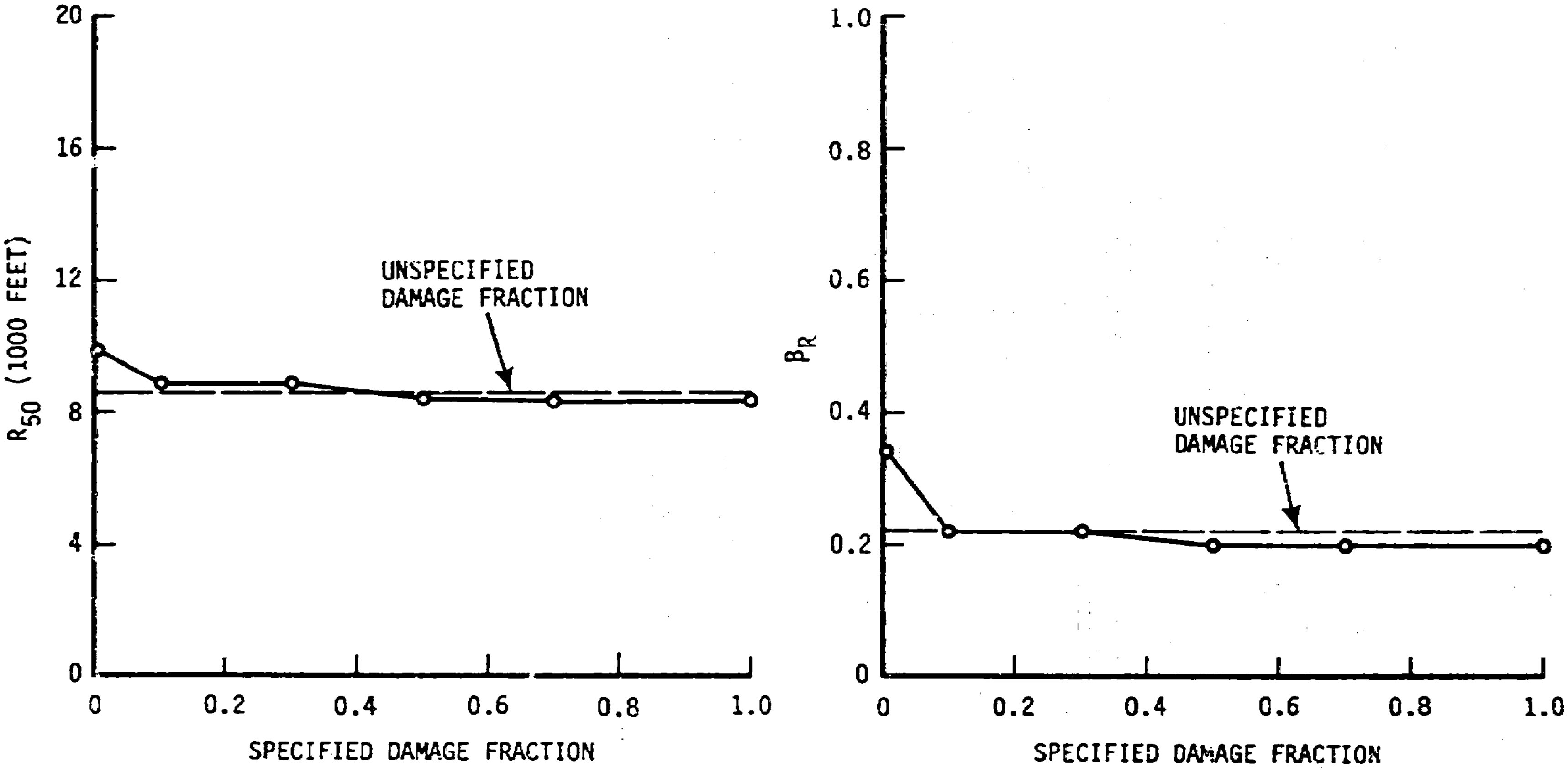


FIGURE 14e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

SINGLE-STORY WOOD FRAME BUILDINGS
STRUCTURAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT

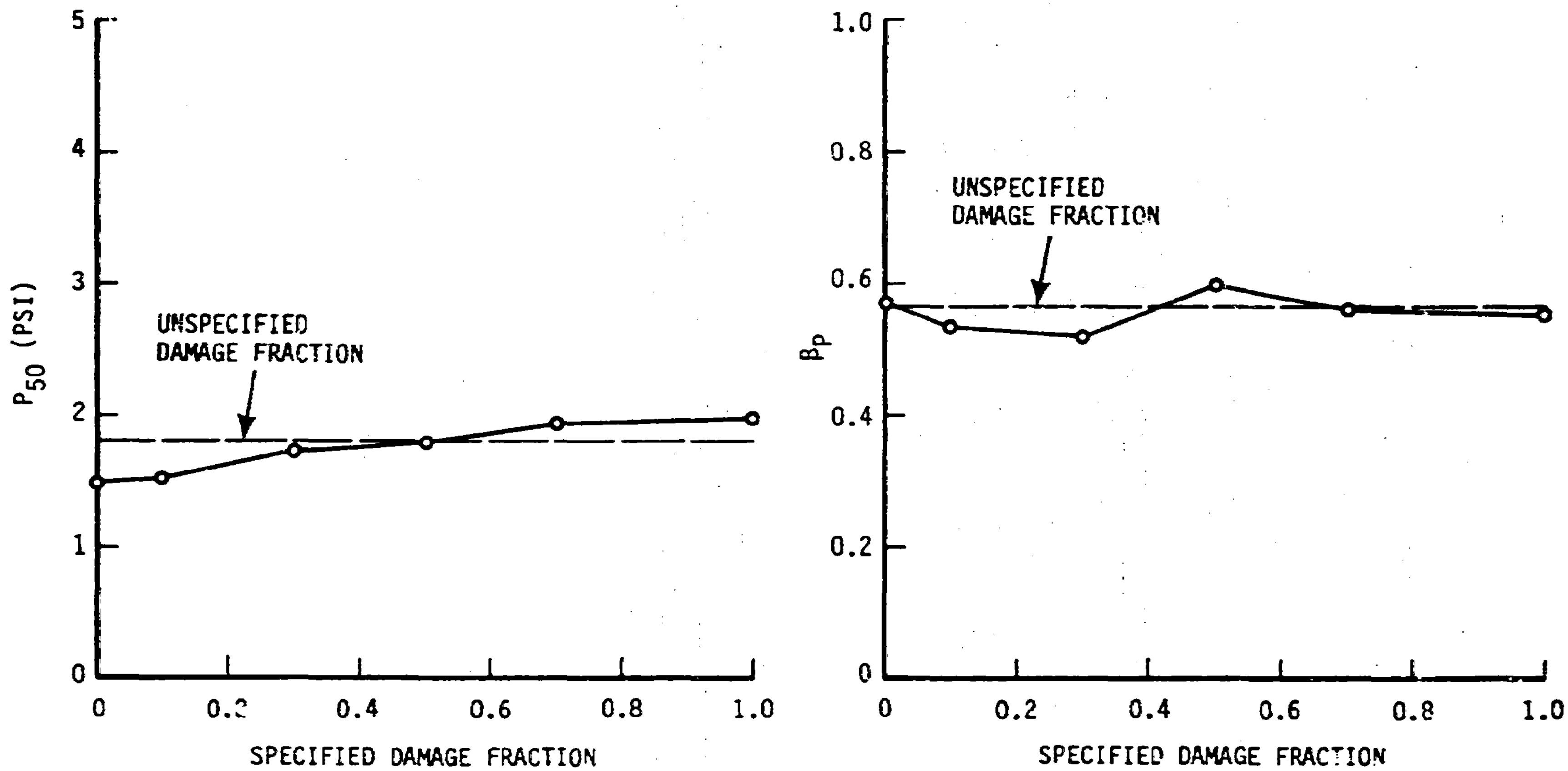


FIGURE 14f

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY WOOD FRAME BUILDINGS

STRUCTURAL DAMAGE CRITERIA

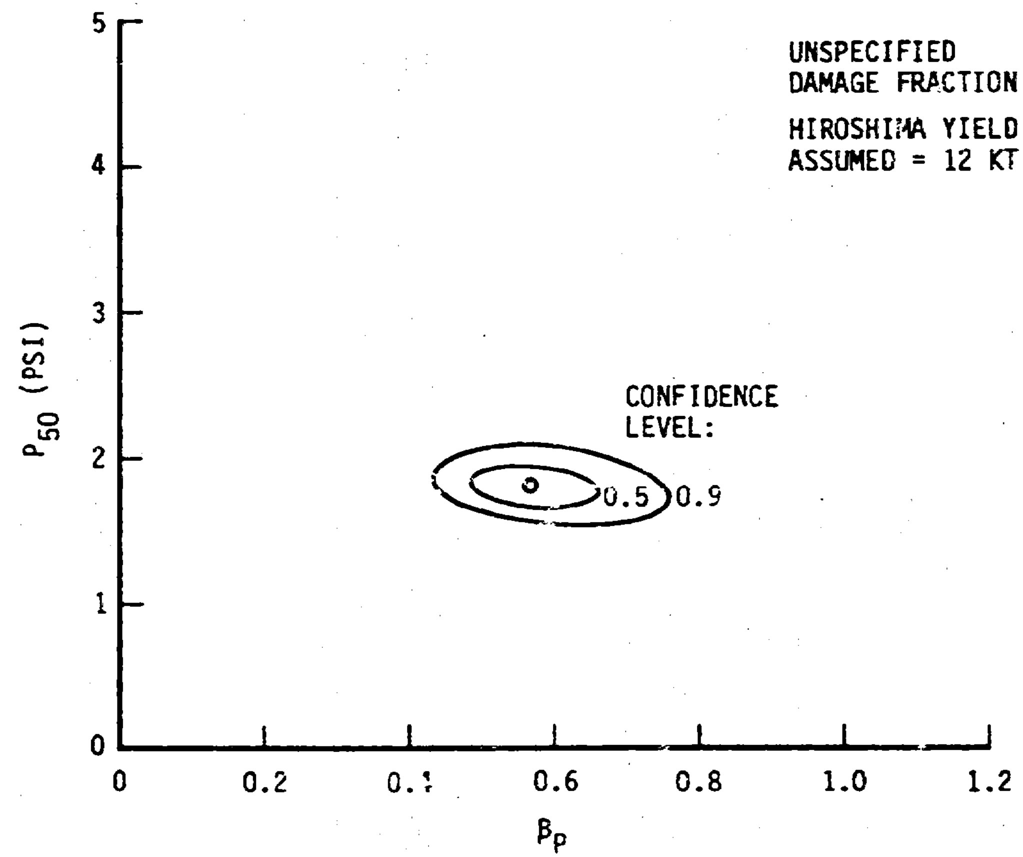


FIGURE 14g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA

STRUCTURAL DAMAGE CRITERIA

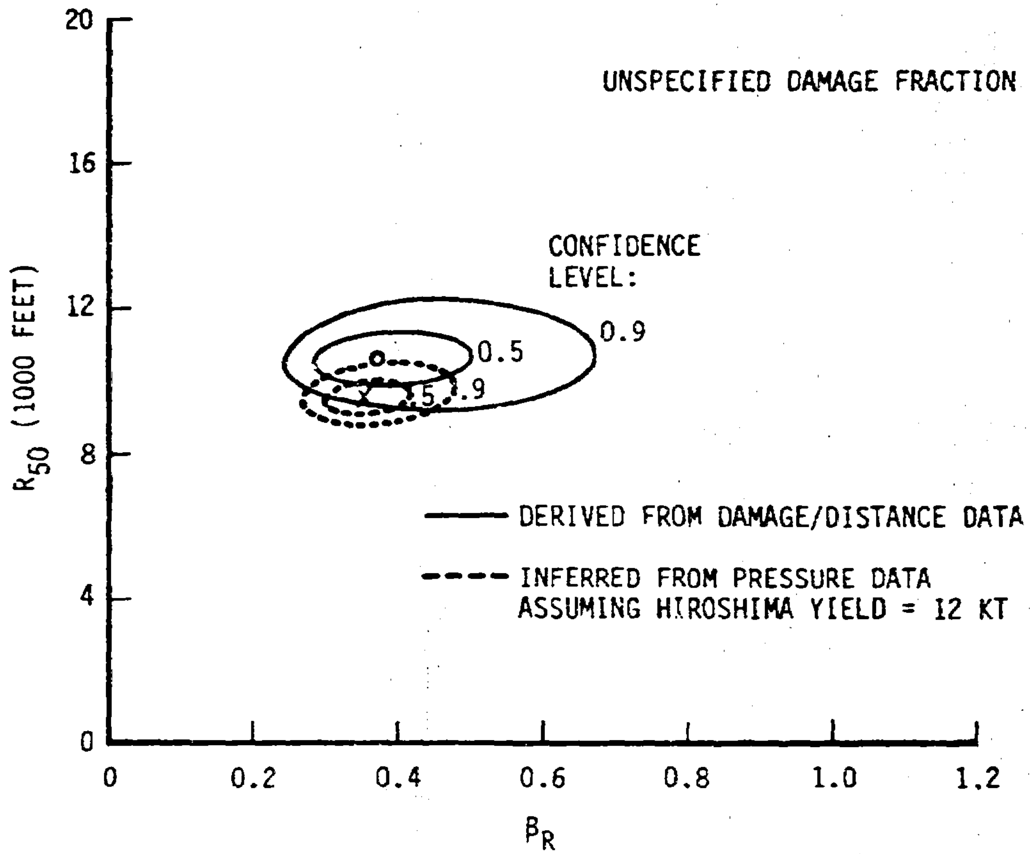


FIGURE 14h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI
STRUCTURAL DAMAGE CRITERIA

UNSPECIFIED DAMAGE FRACTION

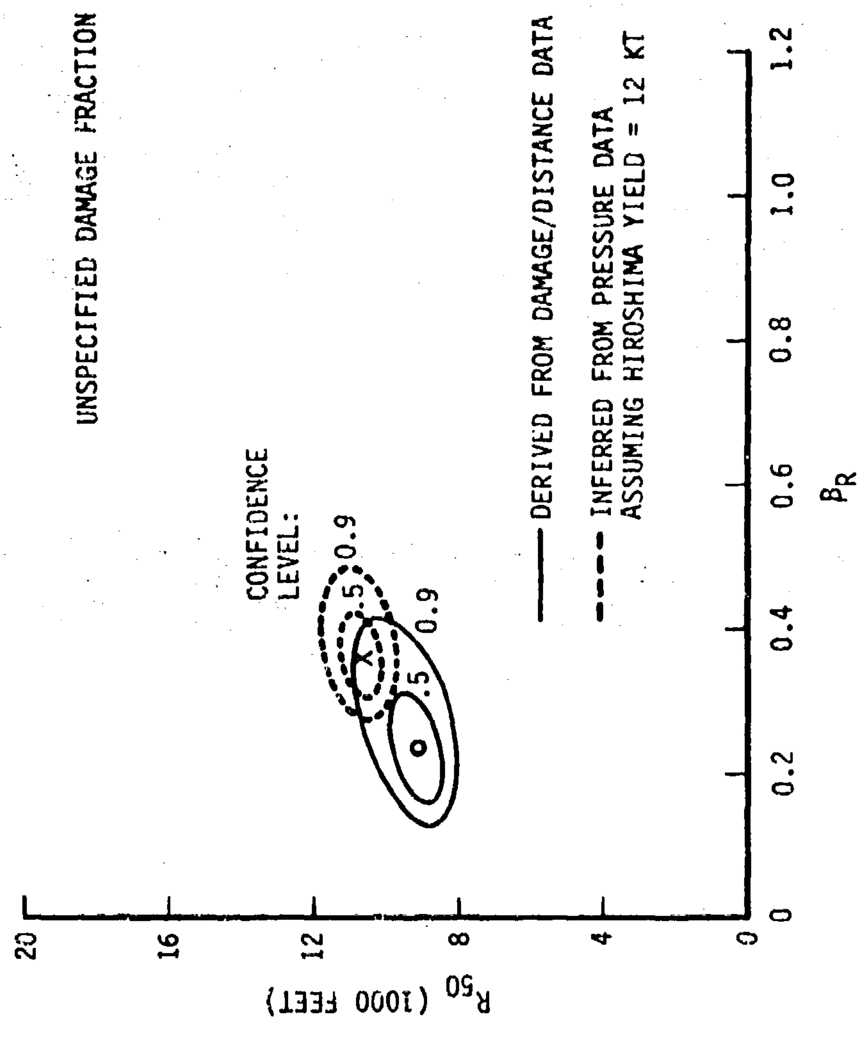


FIGURE 15a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA
WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY
STRUCTURAL DAMAGE CRITERIA

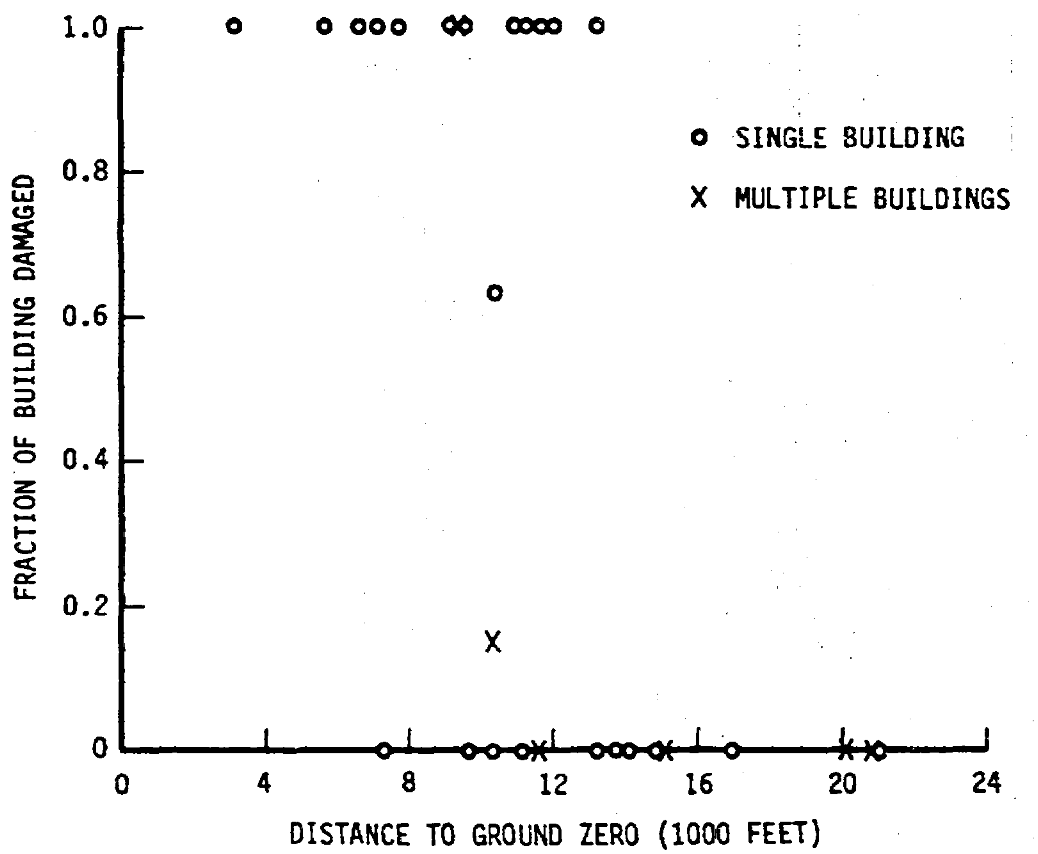


FIGURE 15b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI
WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY
STRUCTURAL DAMAGE CRITERIA

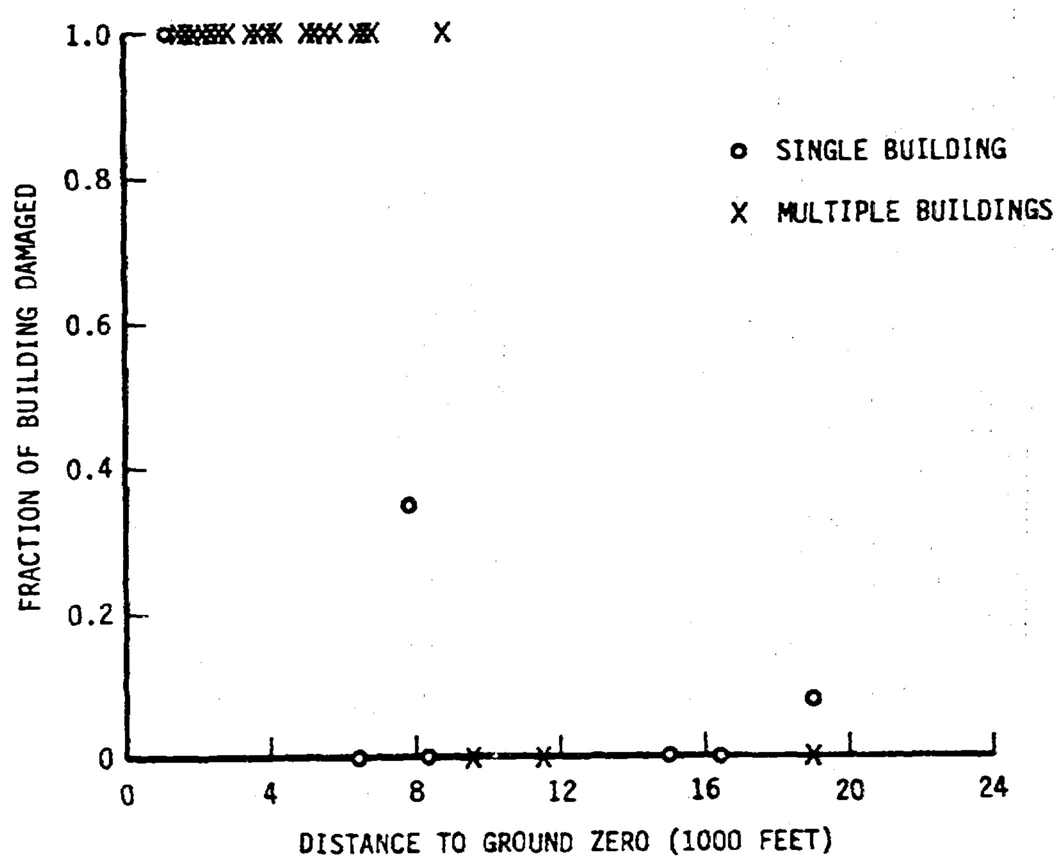


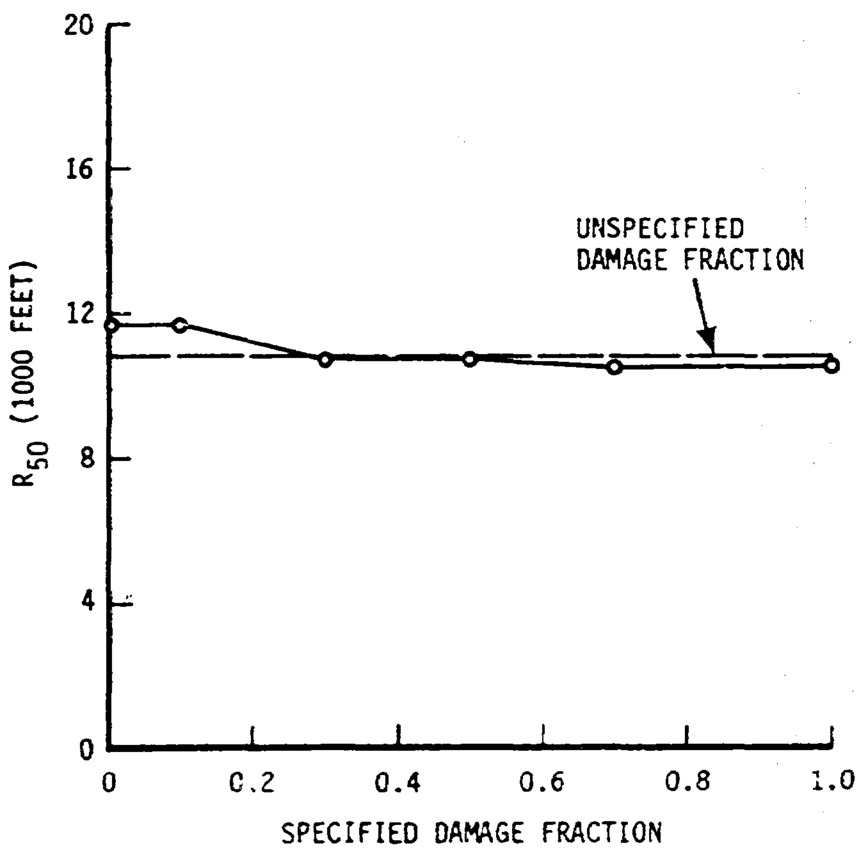
FIGURE 15c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE CRITERIA



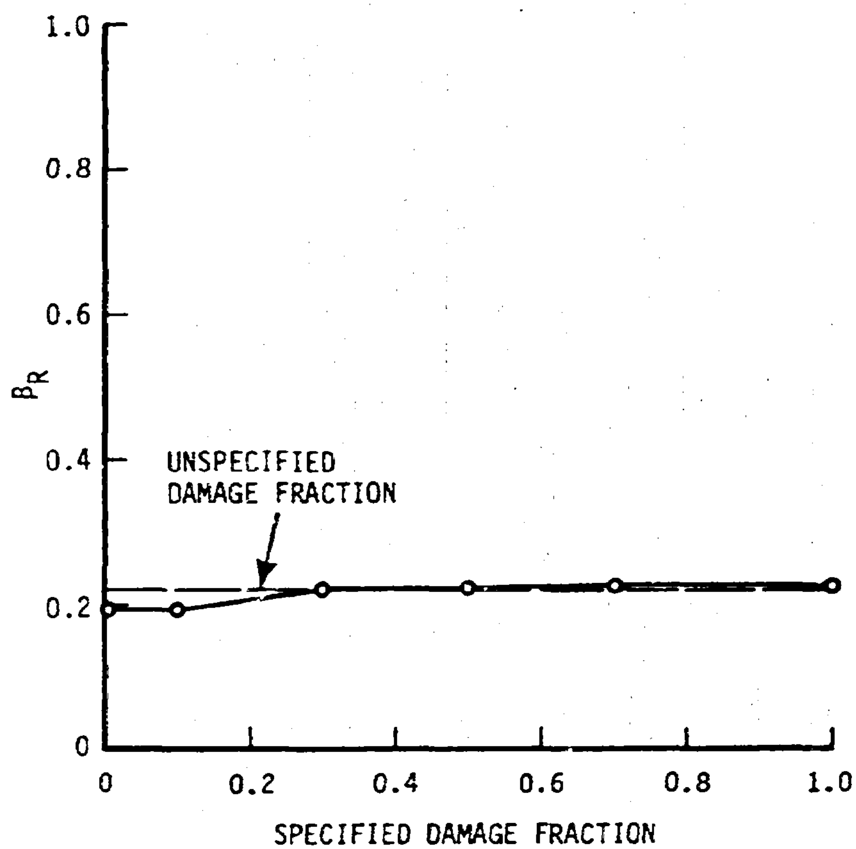


FIGURE 15d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE CRITERIA

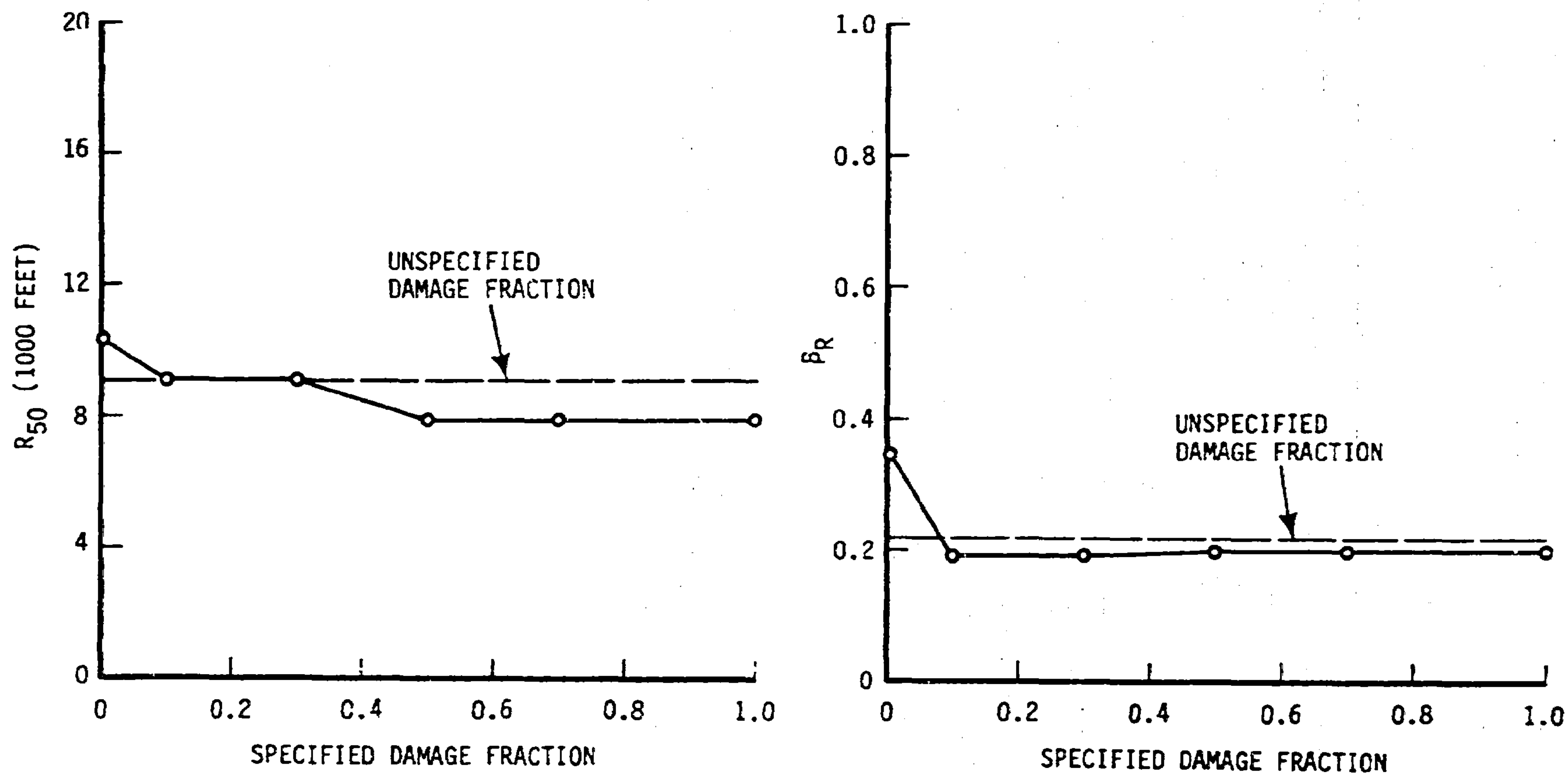


FIGURE 15e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

SINGLE-STORY WOOD FRAME BUILDINGS

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT

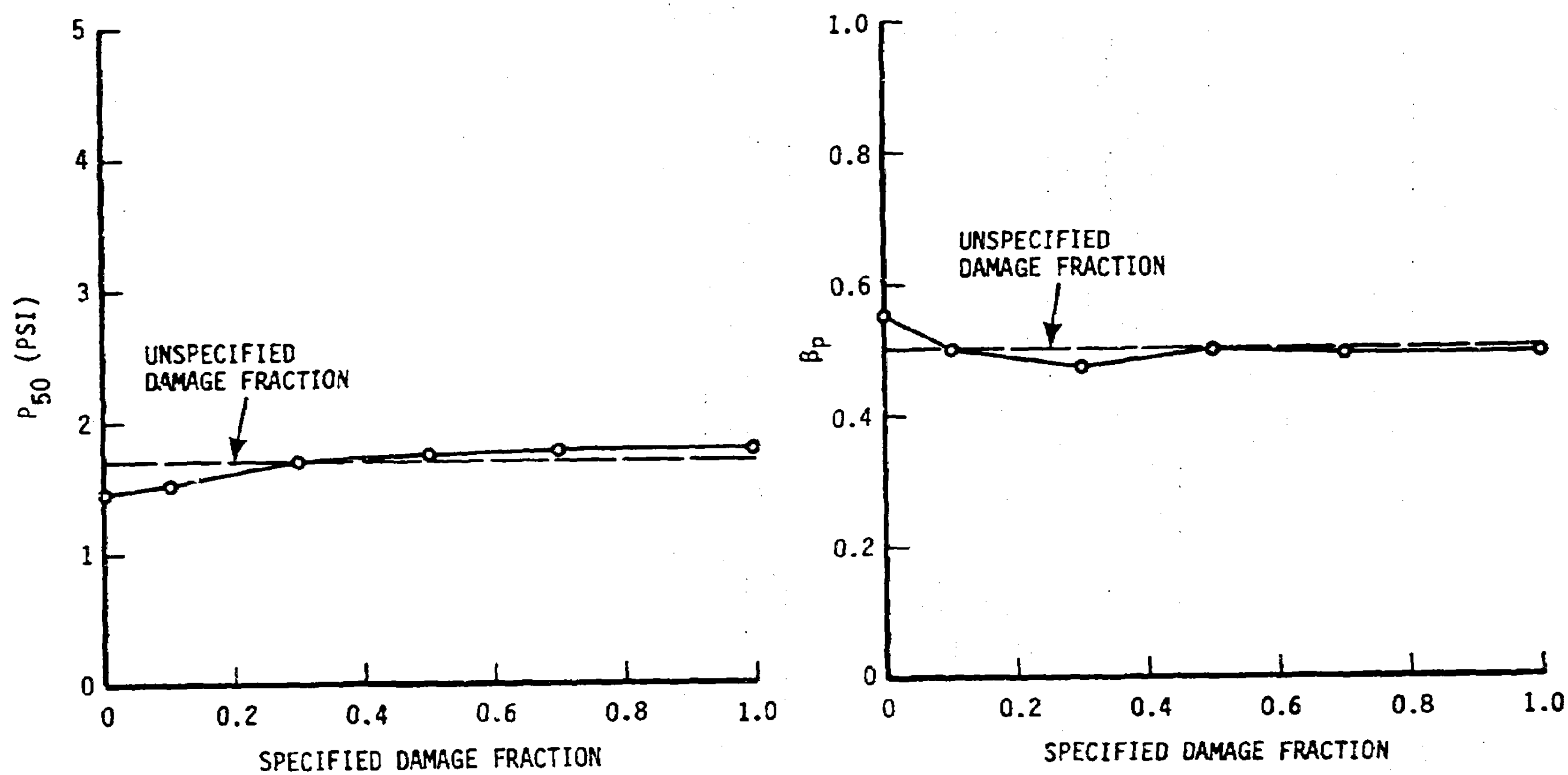


FIGURE 15f

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY WOOD FRAME BUILDINGS

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE CRITERIA

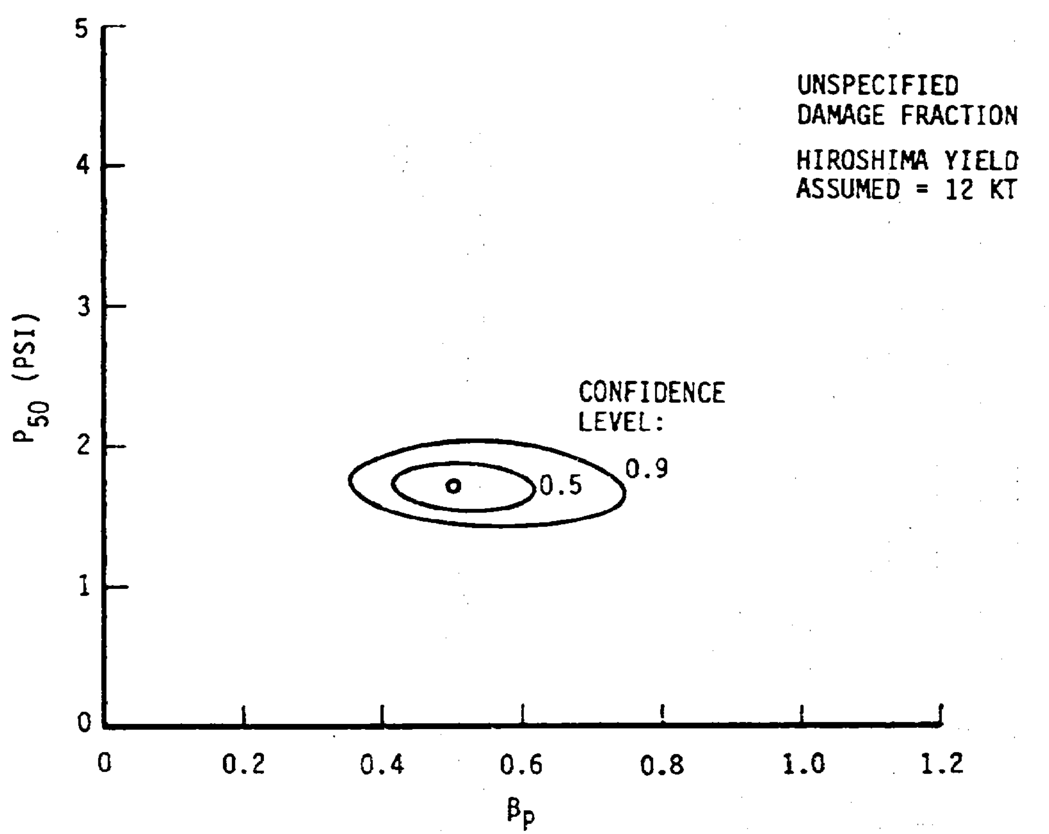


FIGURE 15g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE CRITERIA

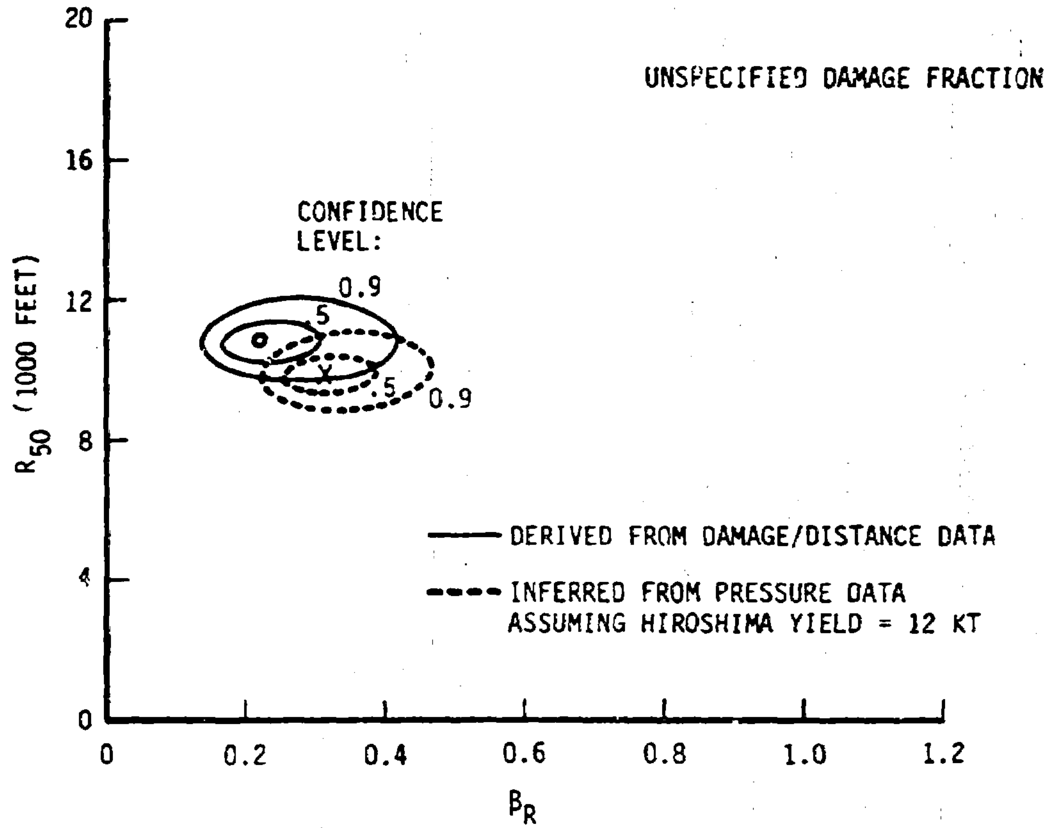


FIGURE 15h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE CRITERIA

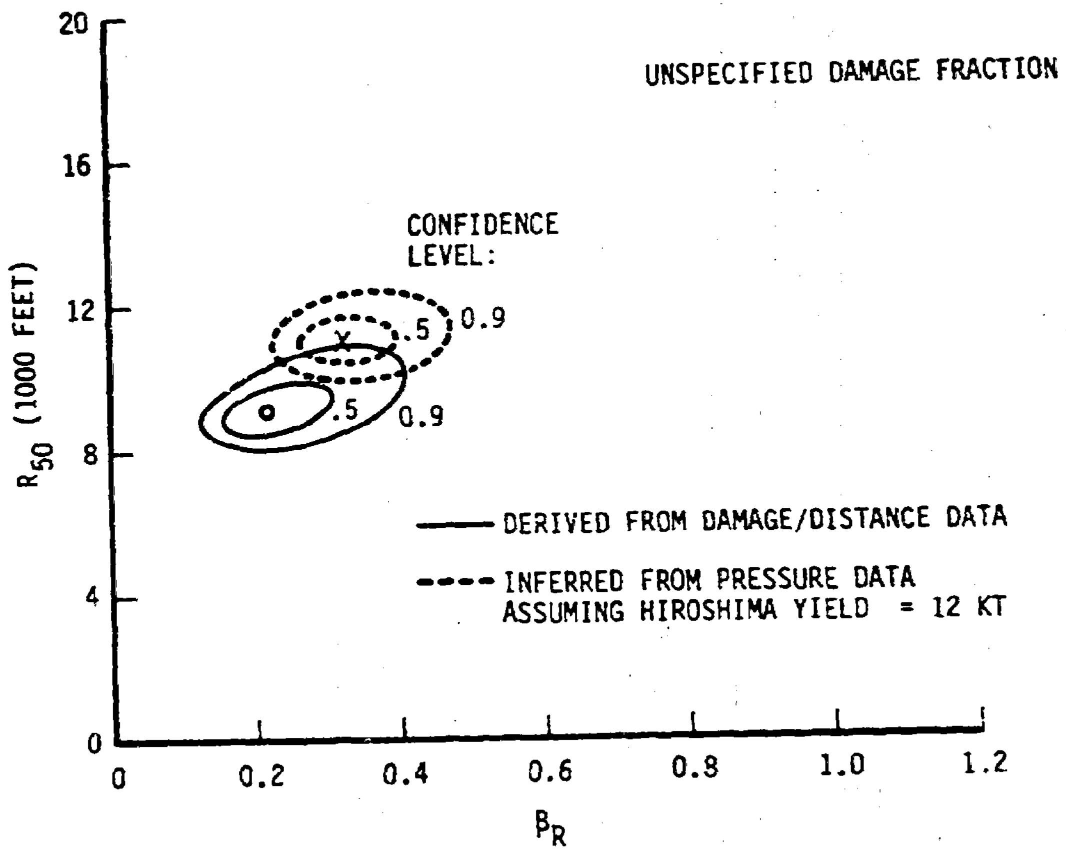


FIGURE 16a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA
SUPERFICIAL DAMAGE CRITERIA

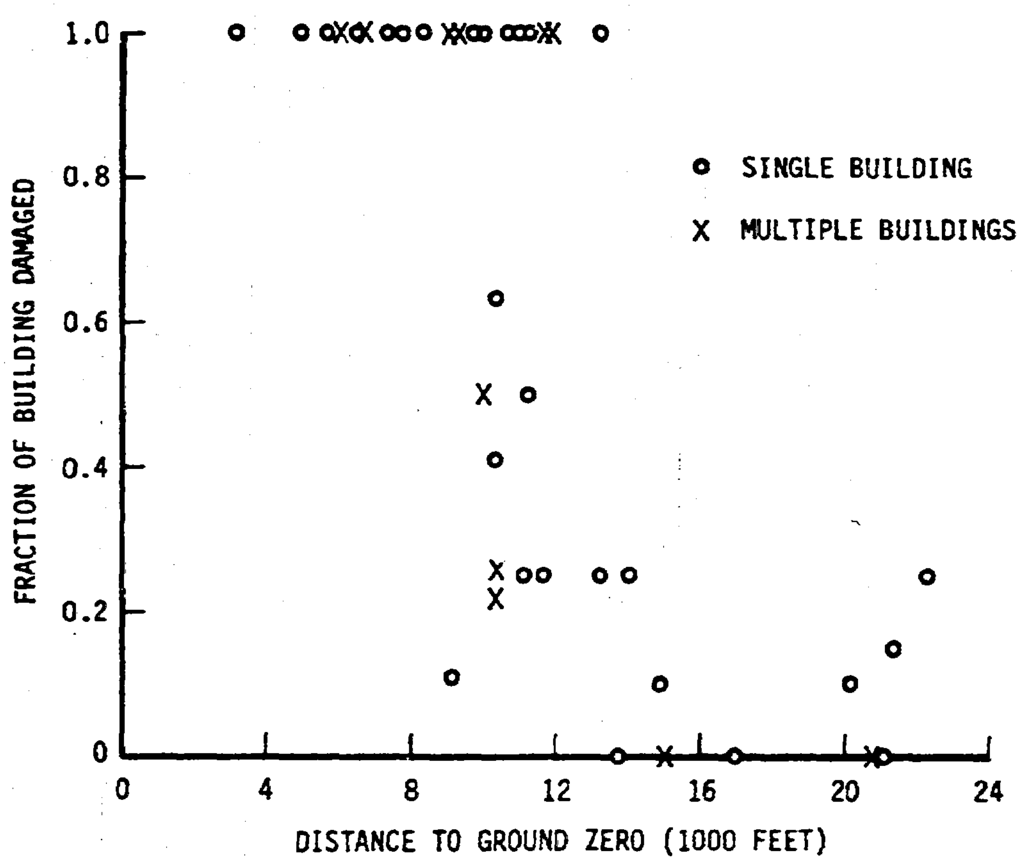


FIGURE 16b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI

SUPERFICIAL DAMAGE CRITERIA

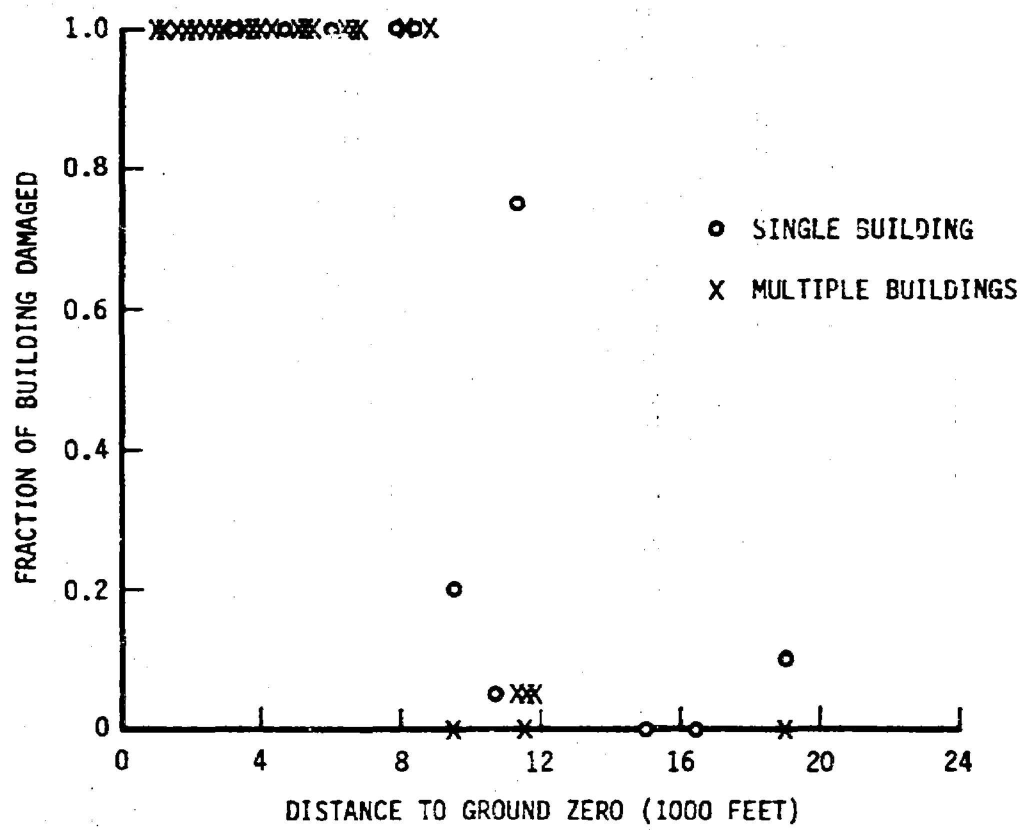


FIGURE 16c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA

SUPERFICIAL DAMAGE CRITERIA

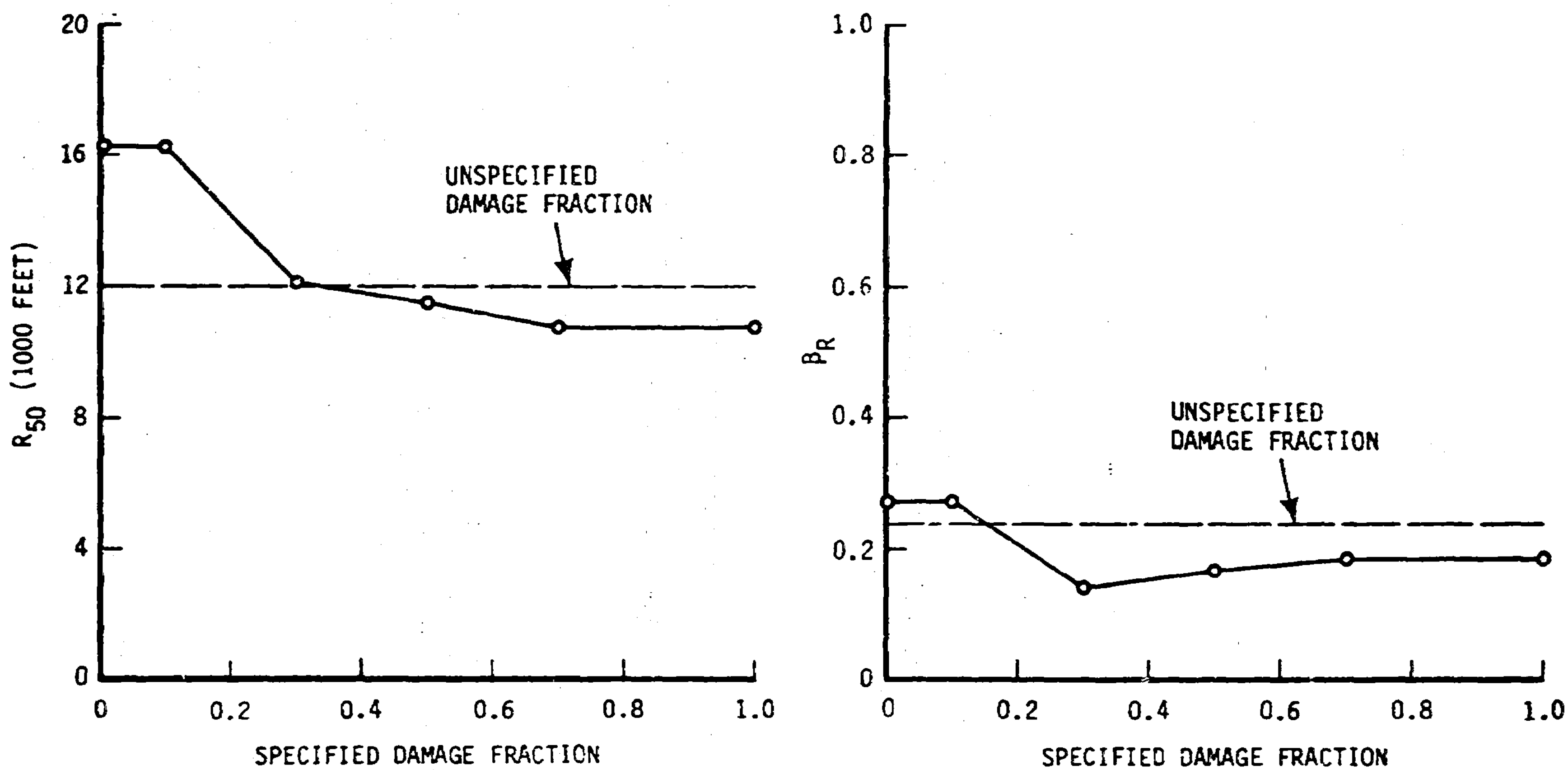


FIGURE 16d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI

SUPERFICIAL DAMAGE CRITERIA

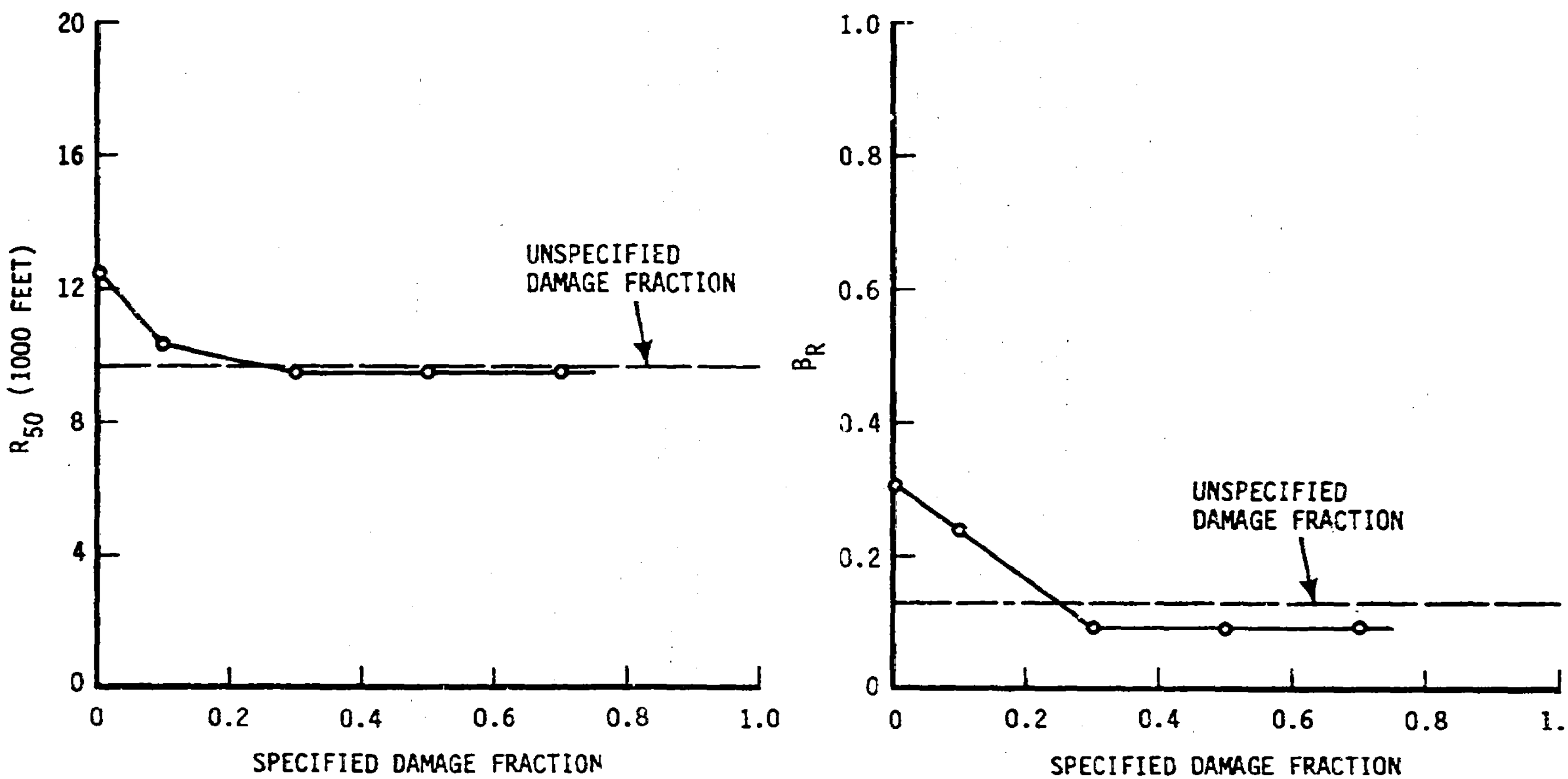
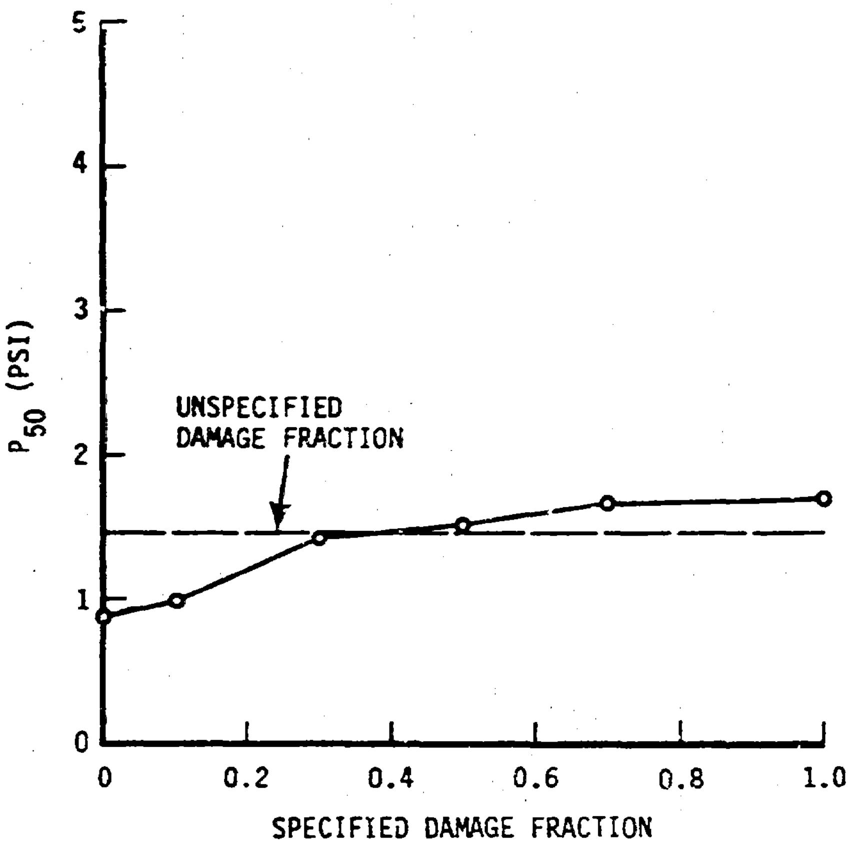


FIGURE 16e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

SINGLE-STORY WOOD FRAME BUILDINGS
SUPERFICIAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT



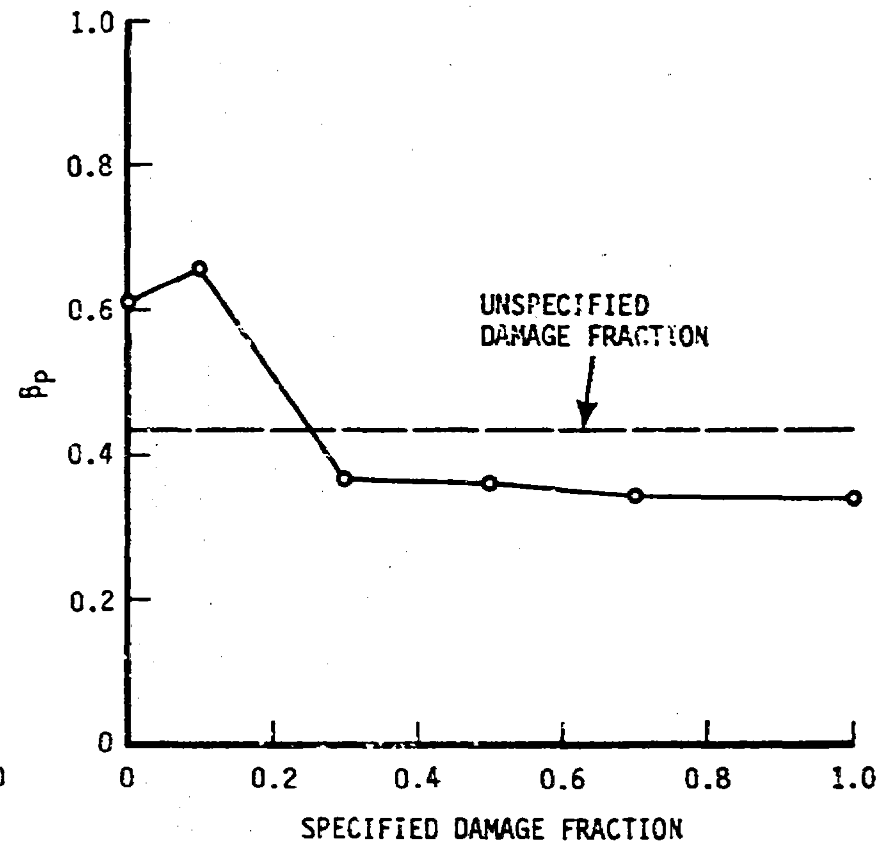


FIGURE 16f

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY WOOD FRAME BUILDINGS

SUPERFICIAL DAMAGE CRITERIA

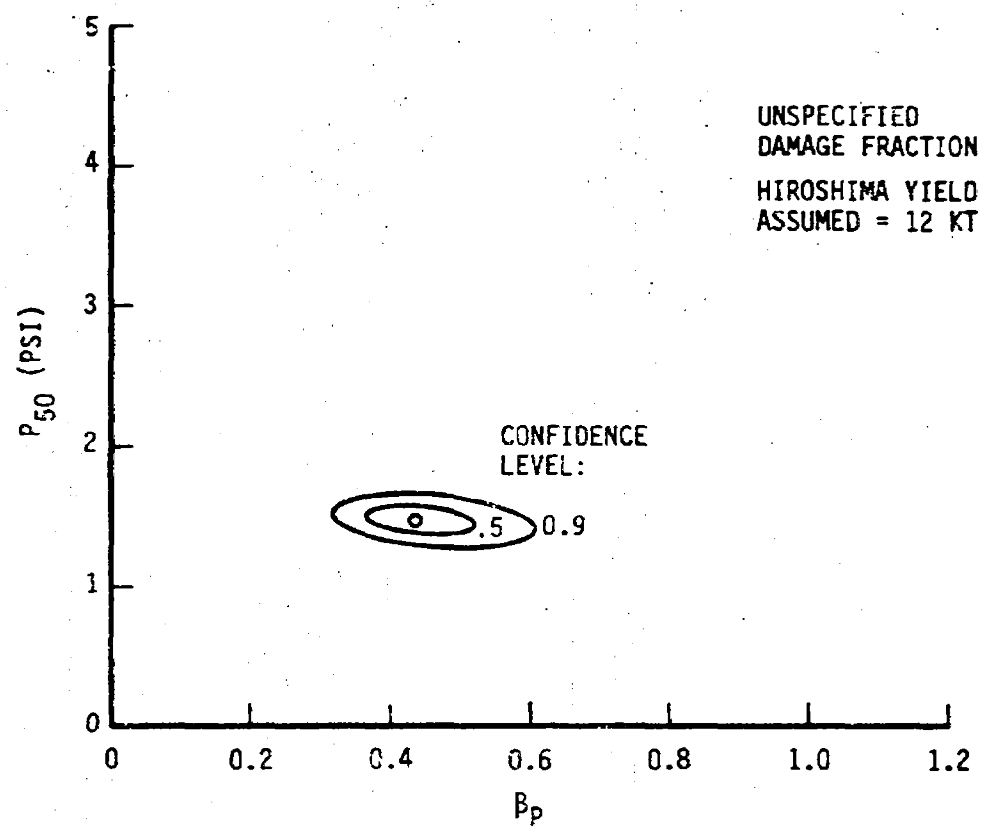


FIGURE 16g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA

SUPERFICIAL DAMAGE CRITERIA

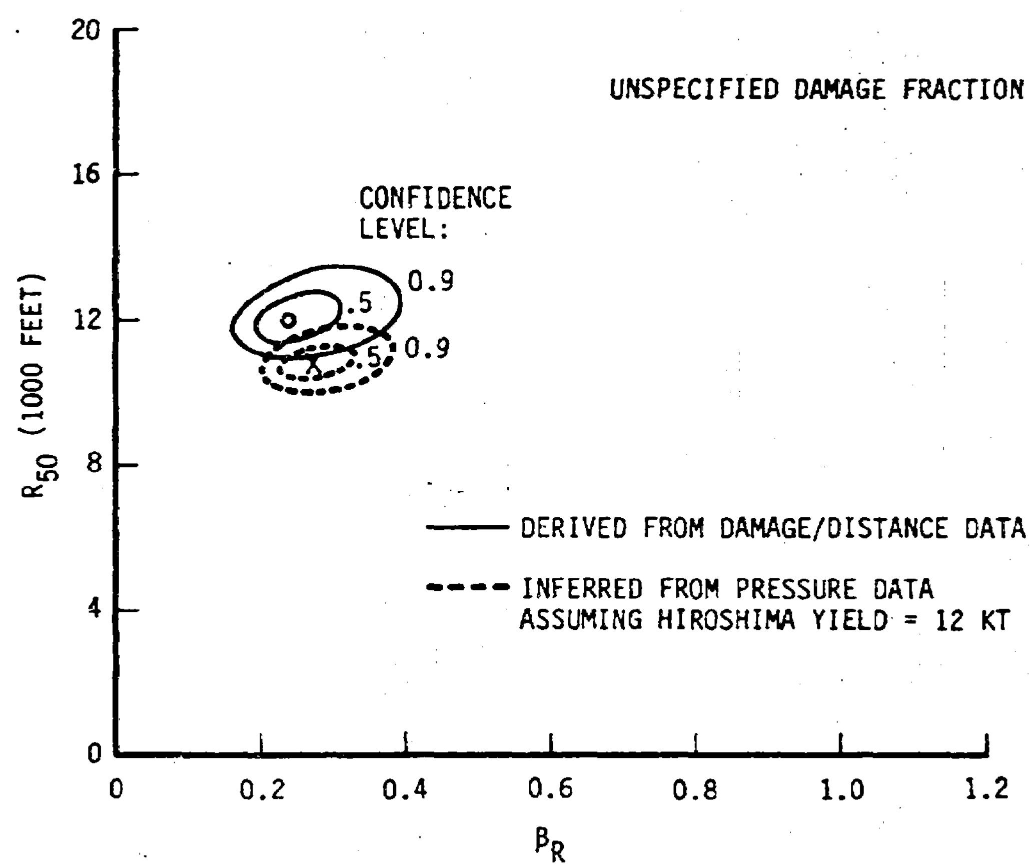


FIGURE 16h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI

SUPERFICIAL DAMAGE CRITERIA

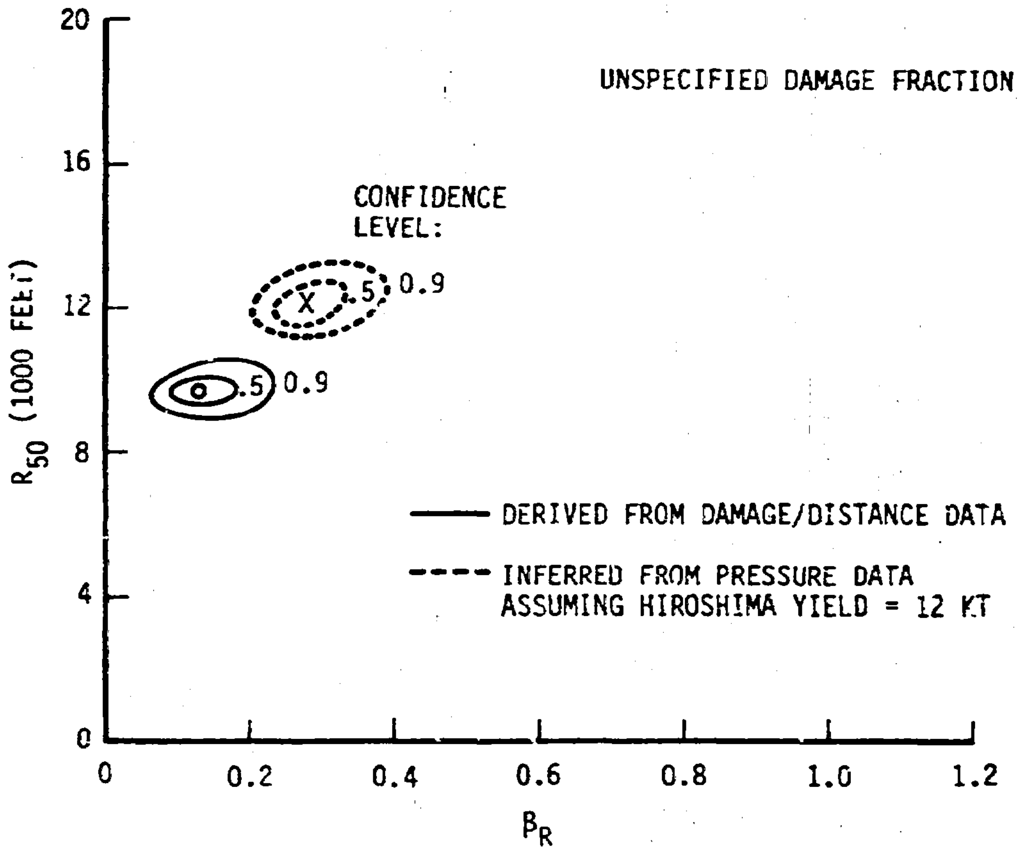


FIGURE 17a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA
WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY
SUPERFICIAL DAMAGE CRITERIA

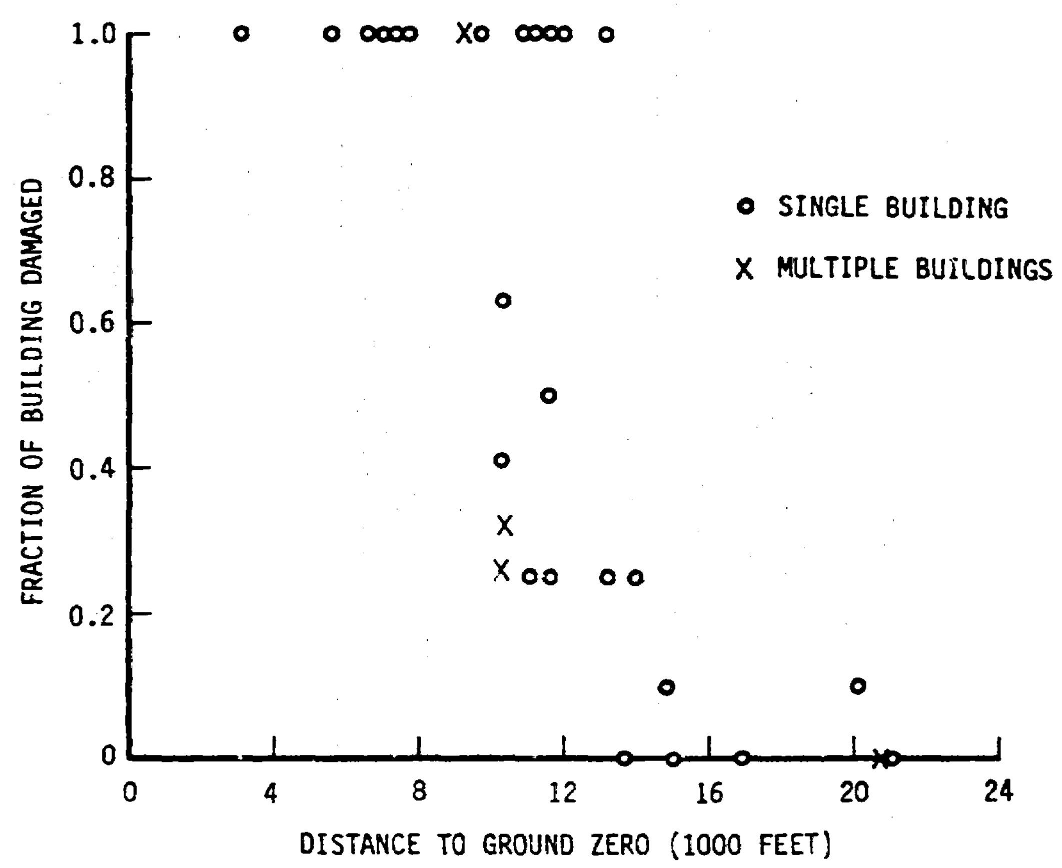


FIGURE 17b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI
WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY
SUPERFICIAL DAMAGE CRITERIA

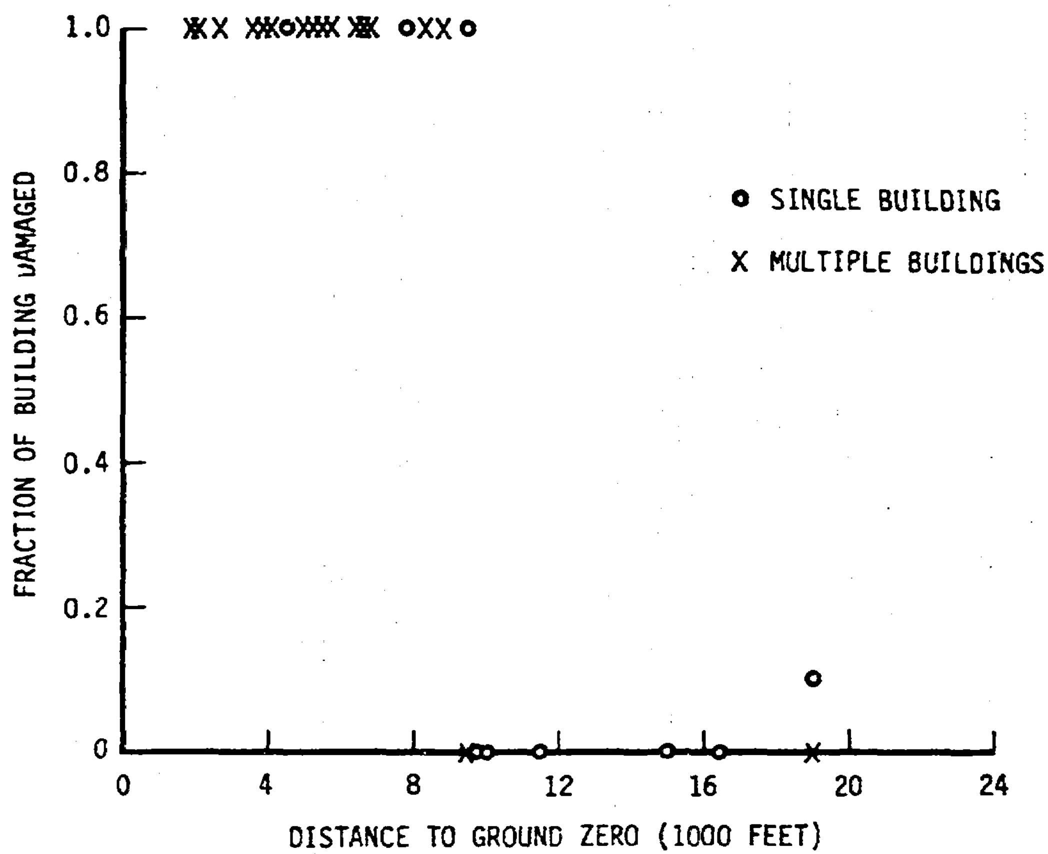


FIGURE 17c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA

WOOD WALLS; WOOD ROOF TRUSSES: ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

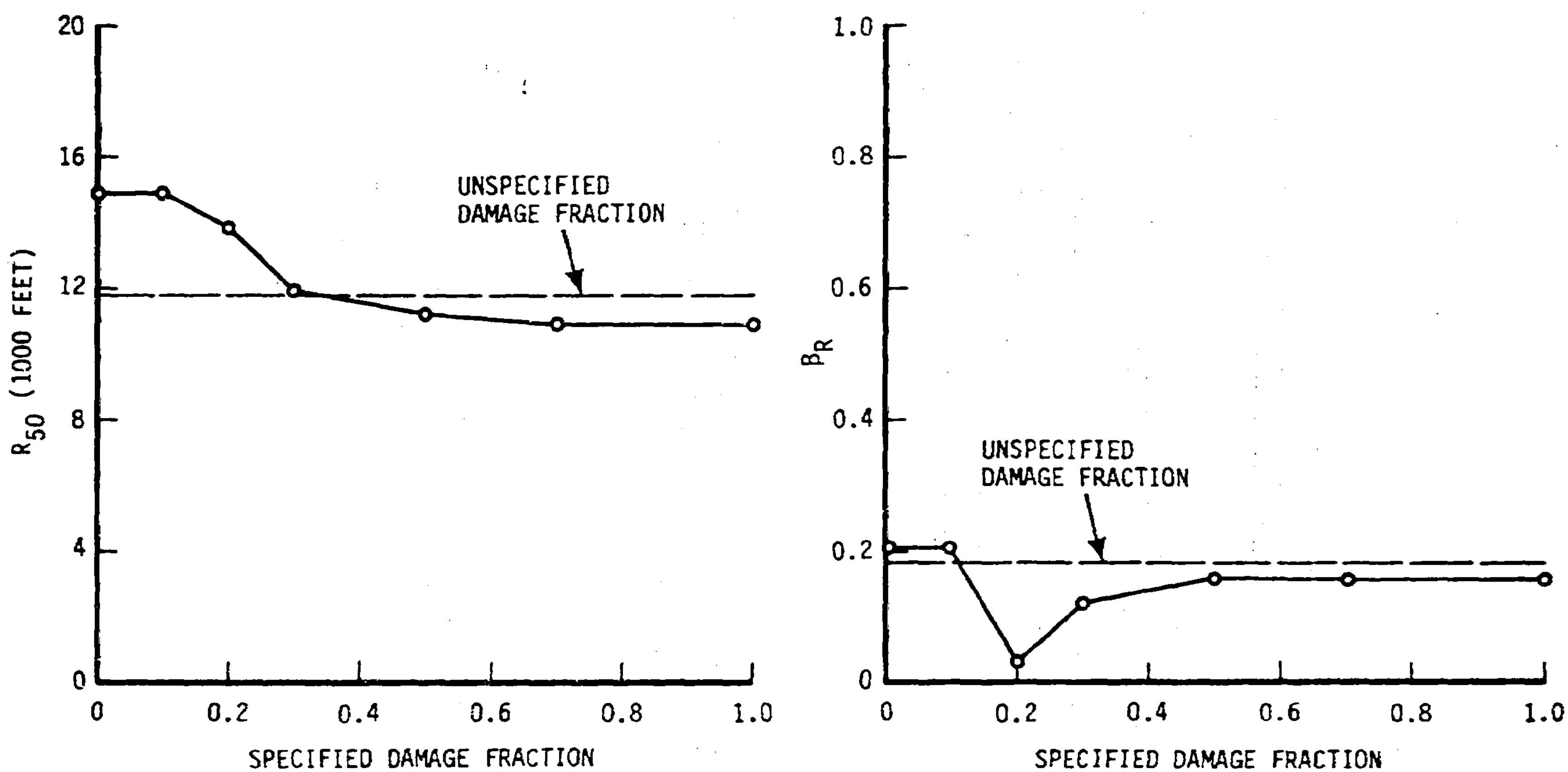


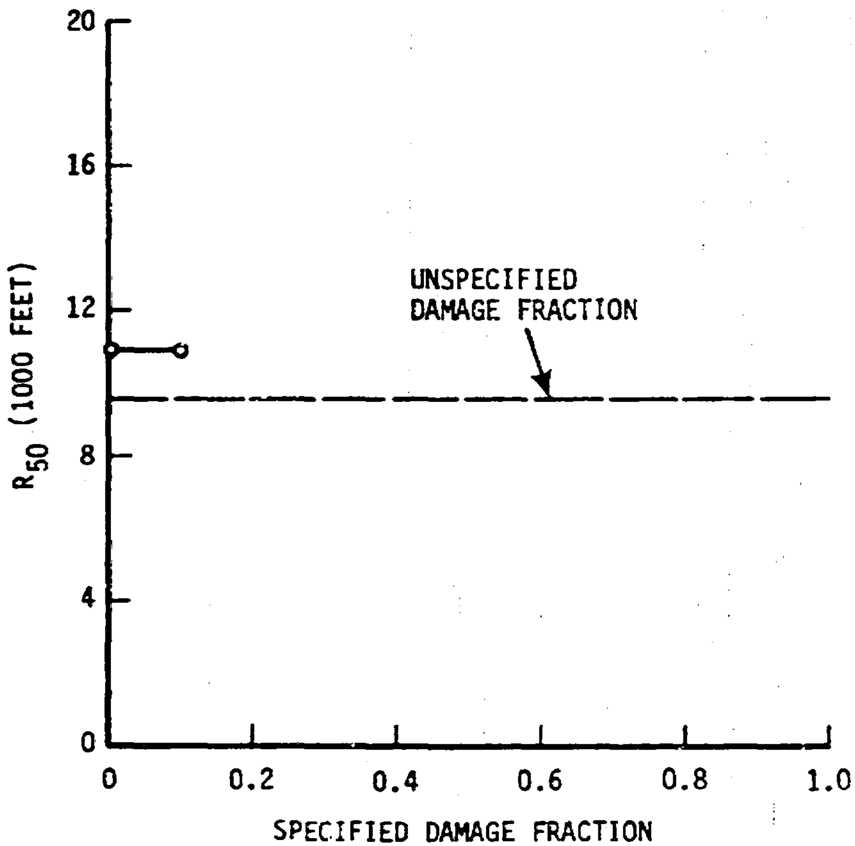
FIGURE 17d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA



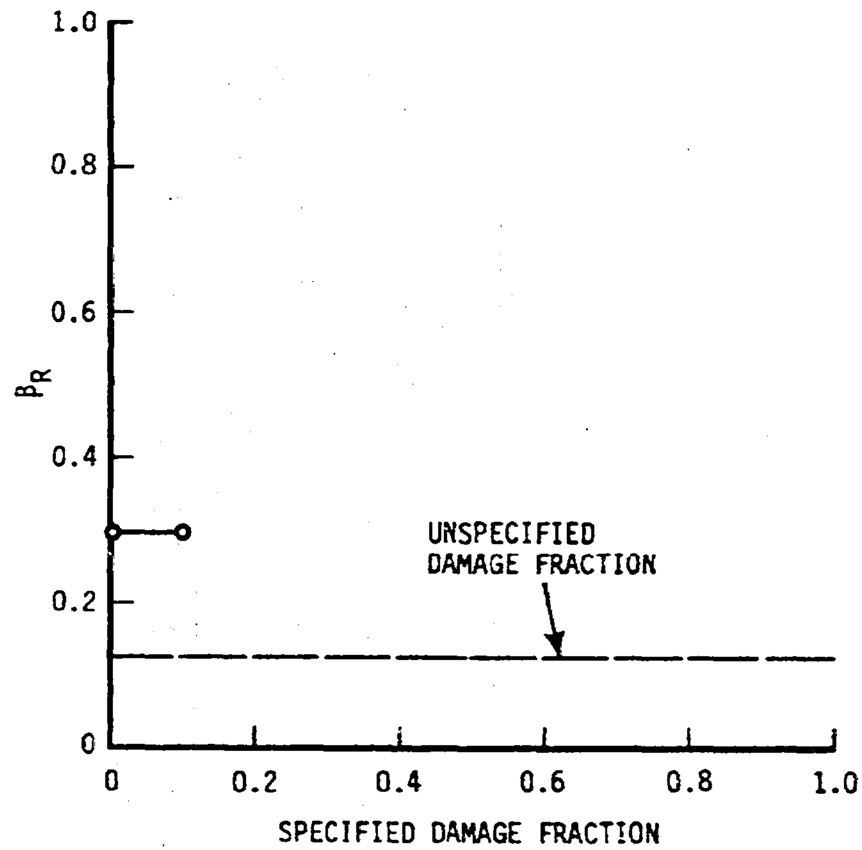


FIGURE 17e

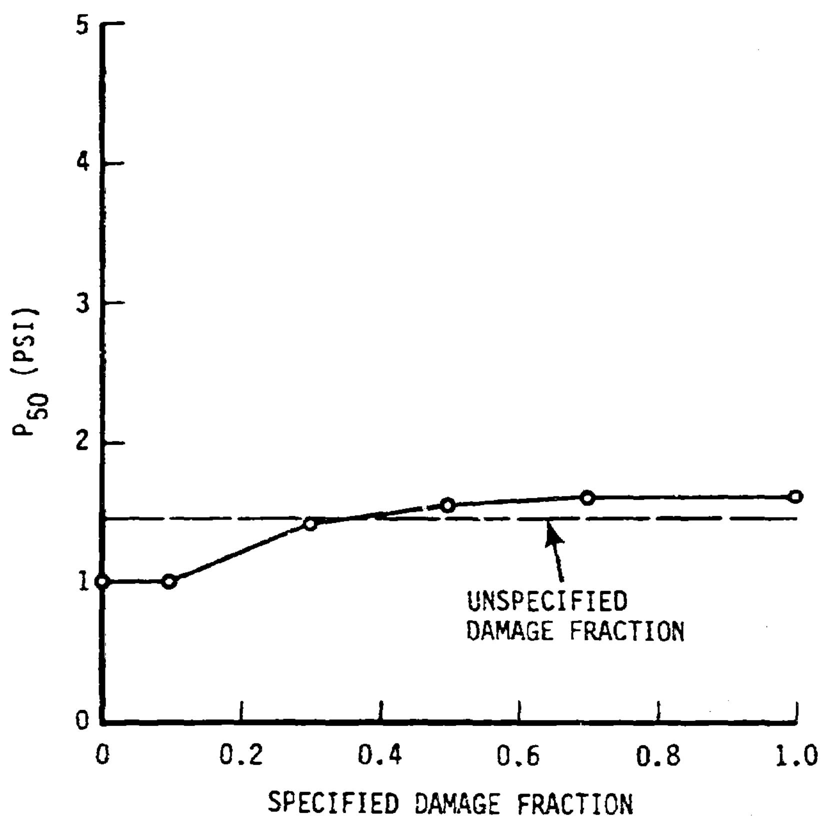
EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

SINGLE-STORY WOOD FRAME BUILDINGS

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT



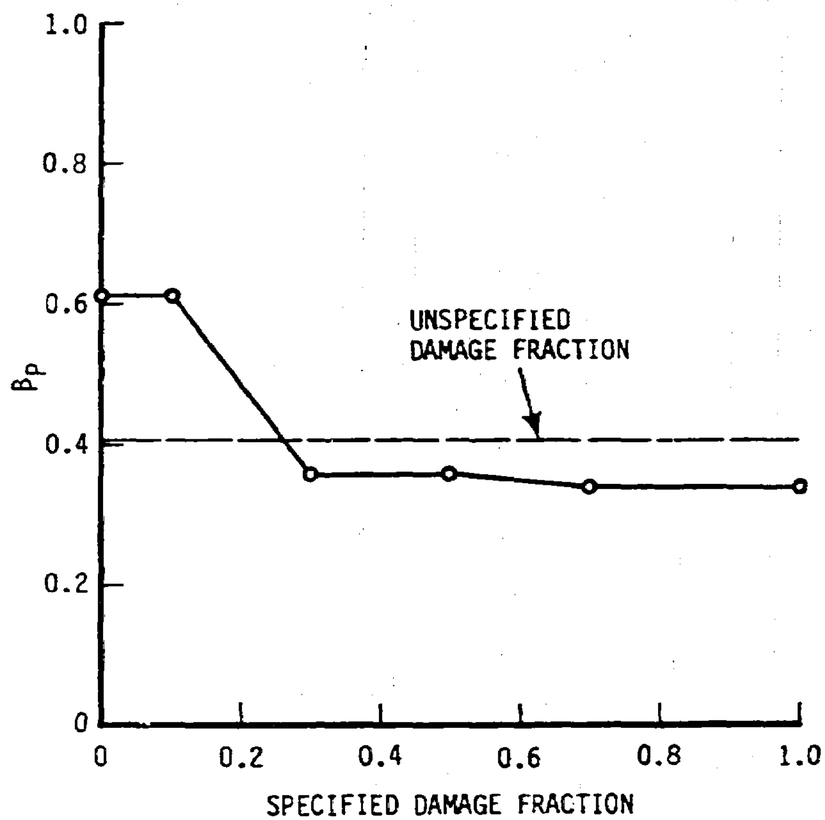


FIGURE 17f

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY WOOD FRAME BUILDINGS

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

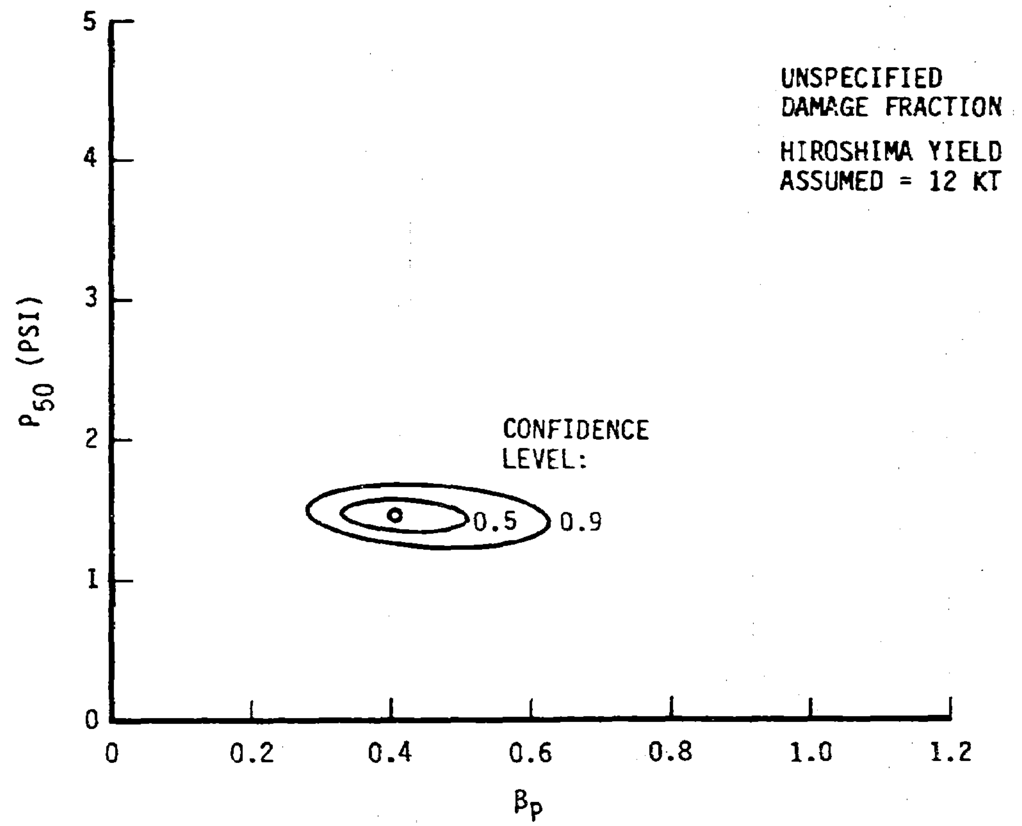


FIGURE 17g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

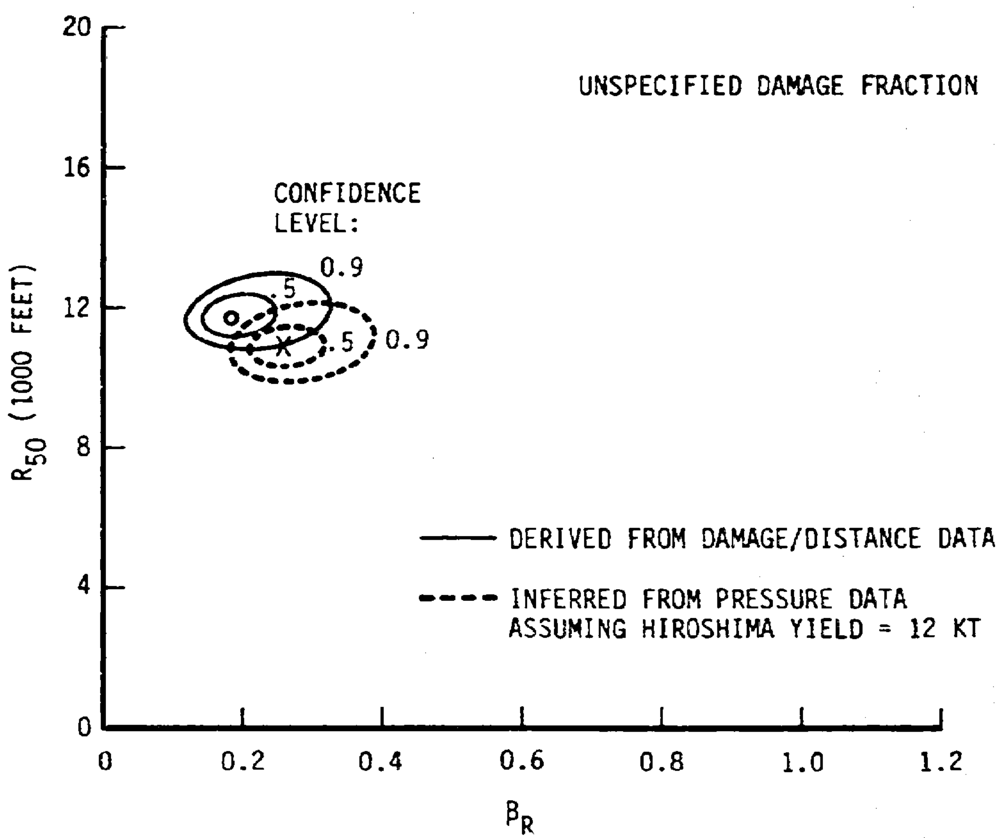


FIGURE 17h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

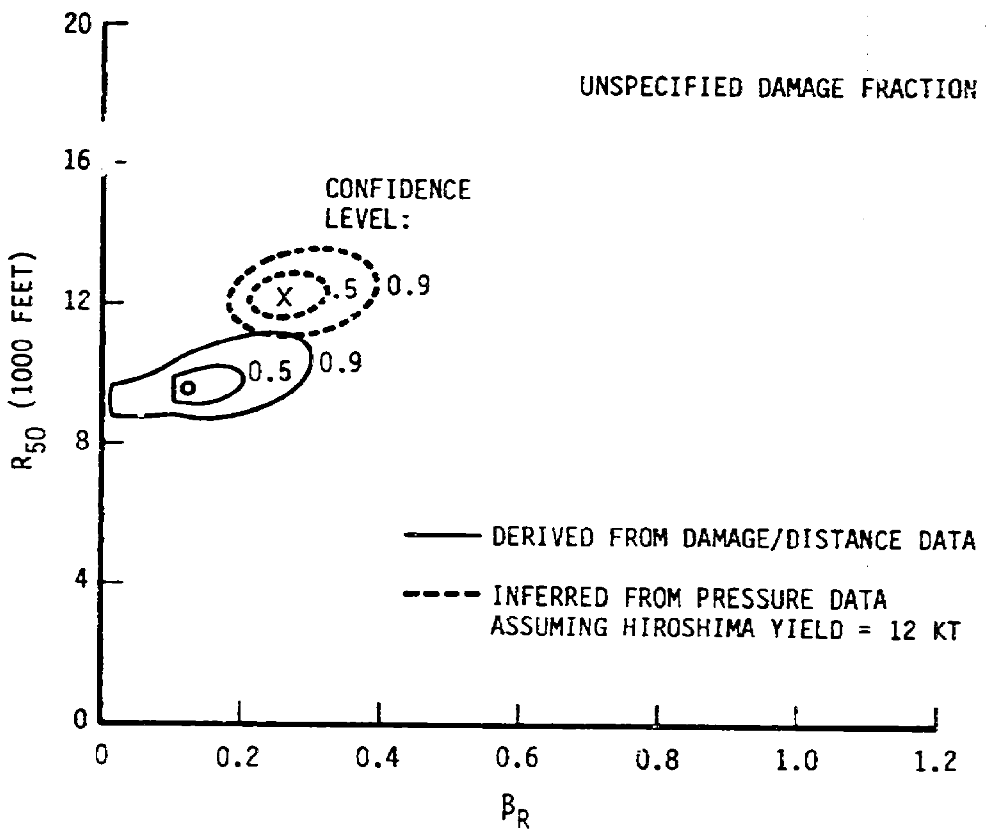


FIGURE 18a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS QUICKLY

SUPERFICIAL DAMAGE CRITERIA

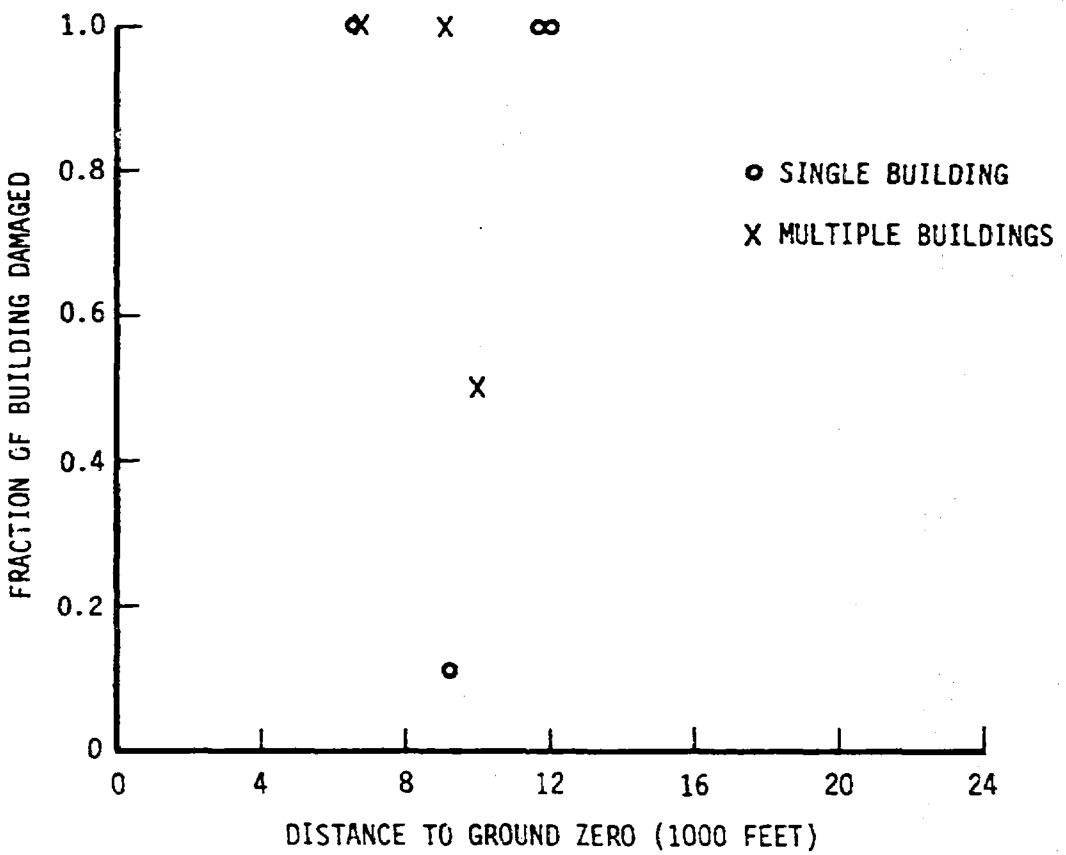


FIGURE 18b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS QUICKLY

SUPERFICIAL DAMAGE CRITERIA

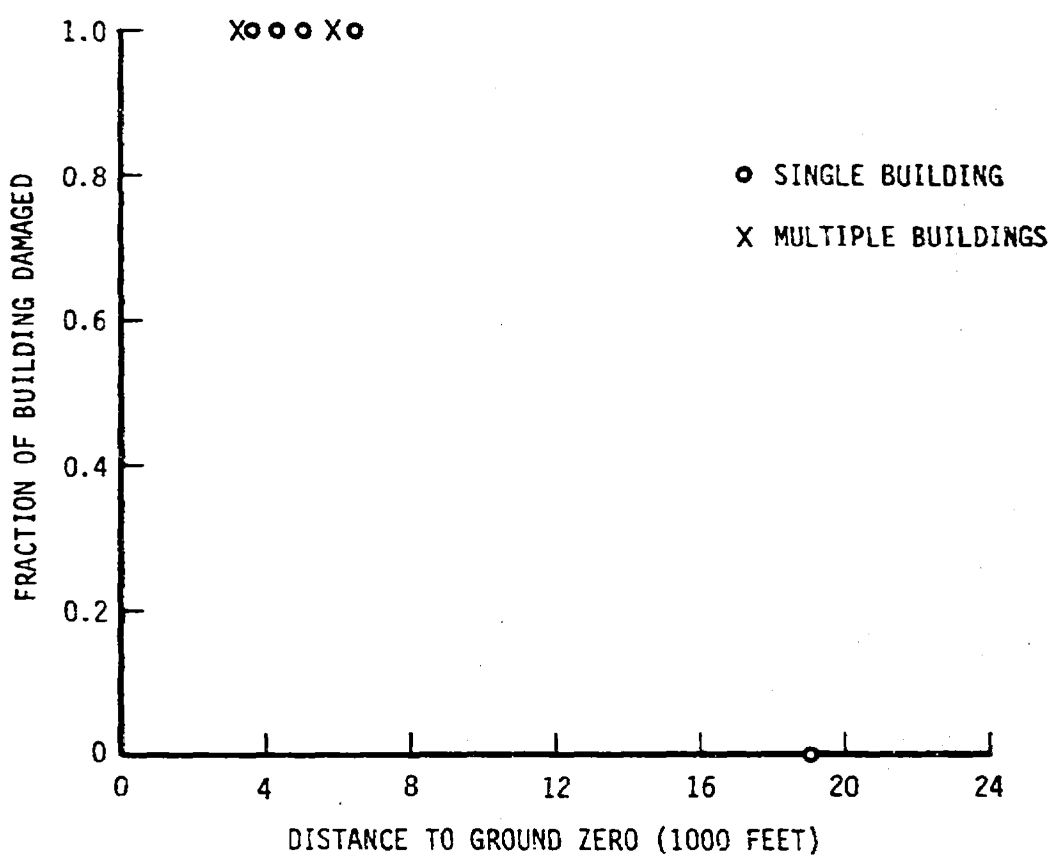


FIGURE 18c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS QUICKLY

SUPERFICIAL DAMAGE CRITERIA

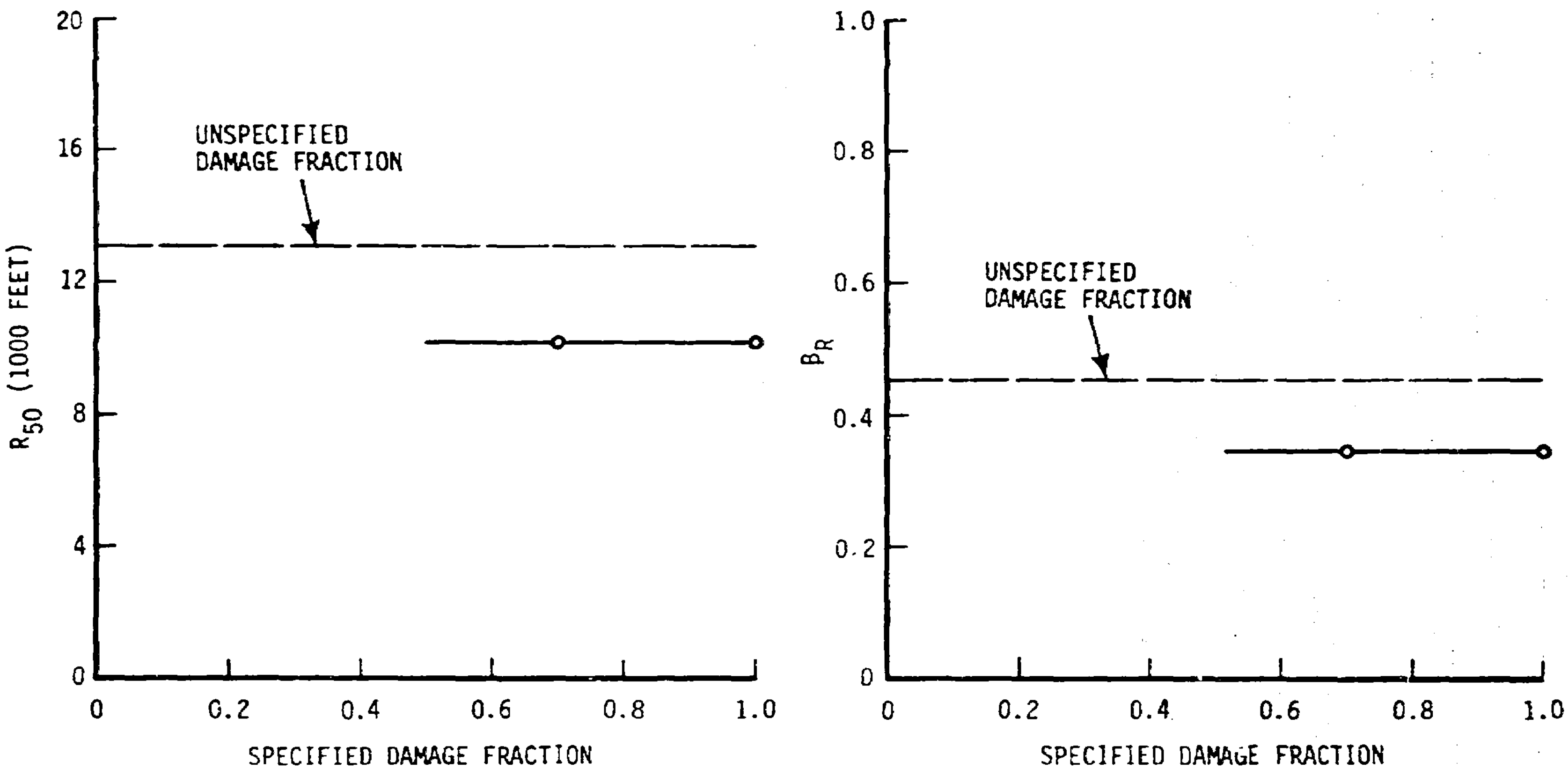


FIGURE 18d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS QUICKLY

SUPERFICIAL DAMAGE CRITERIA

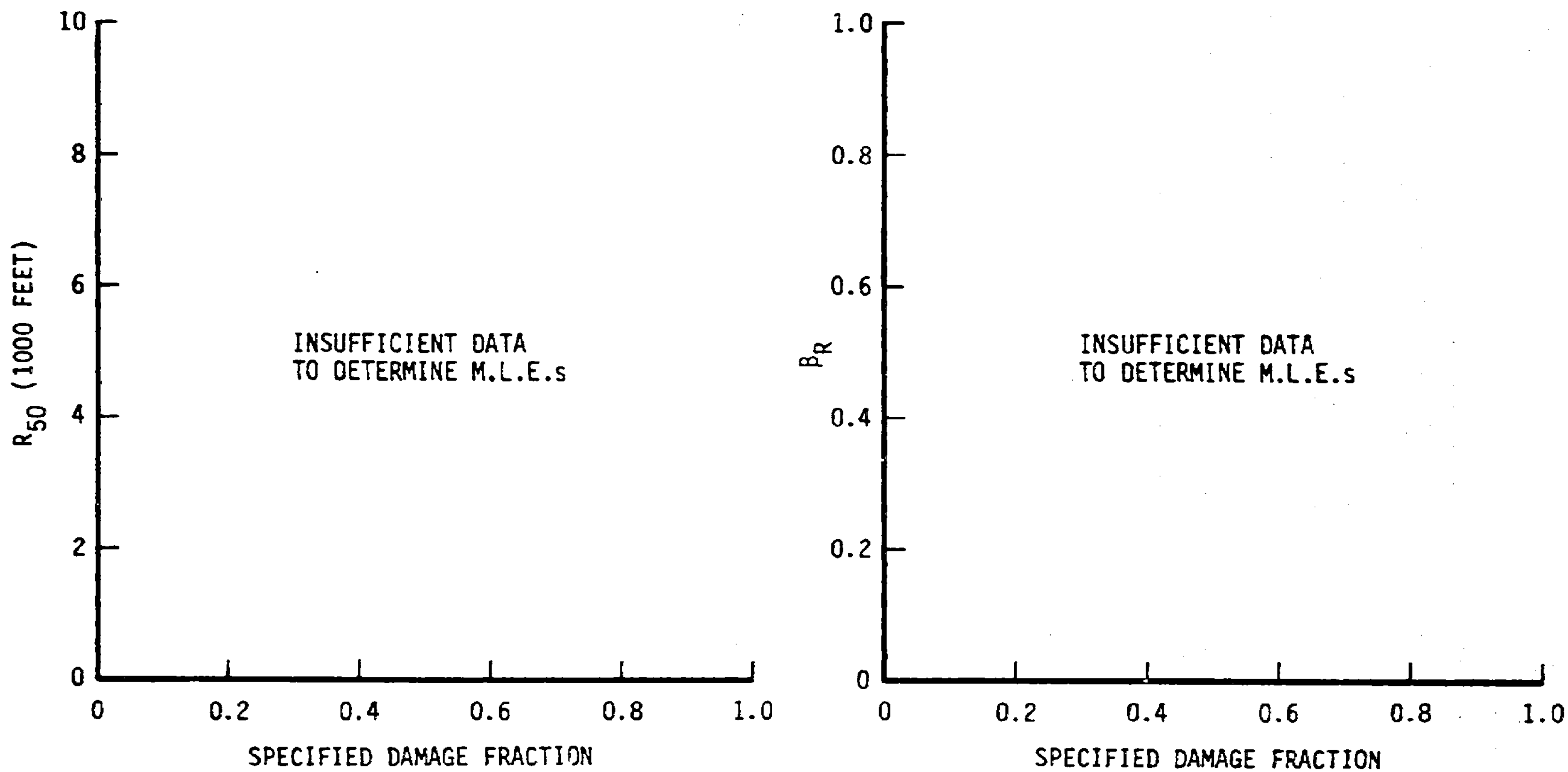


FIGURE 13e

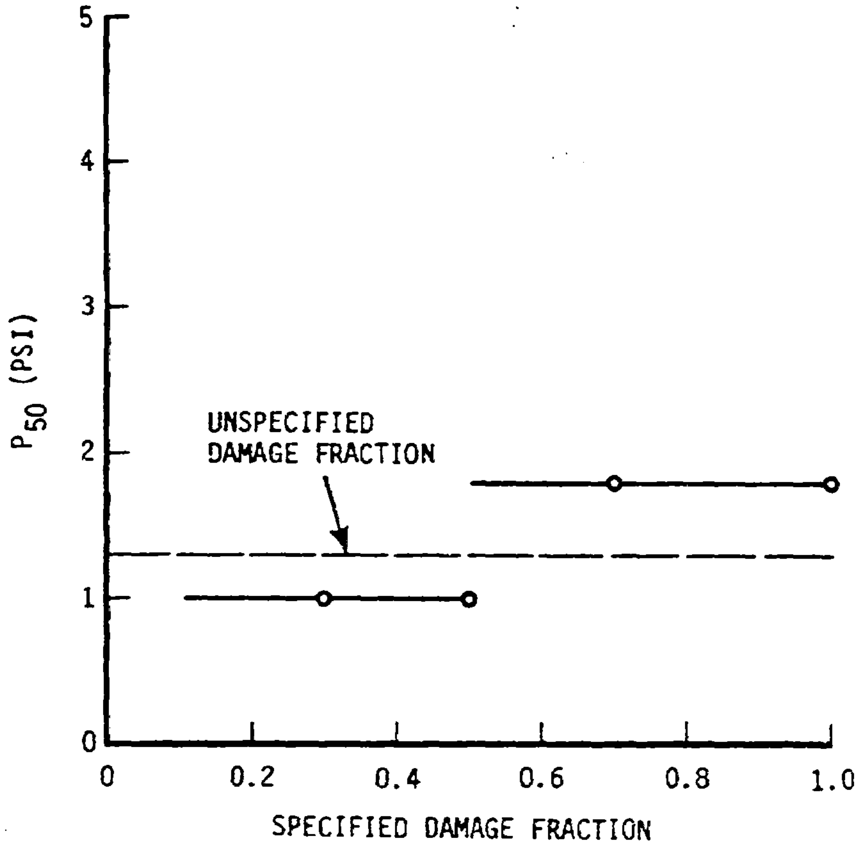
EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

SINGLE-STORY WOOD FRAME BUILDINGS

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS QUICKLY

SUPERFICIAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT



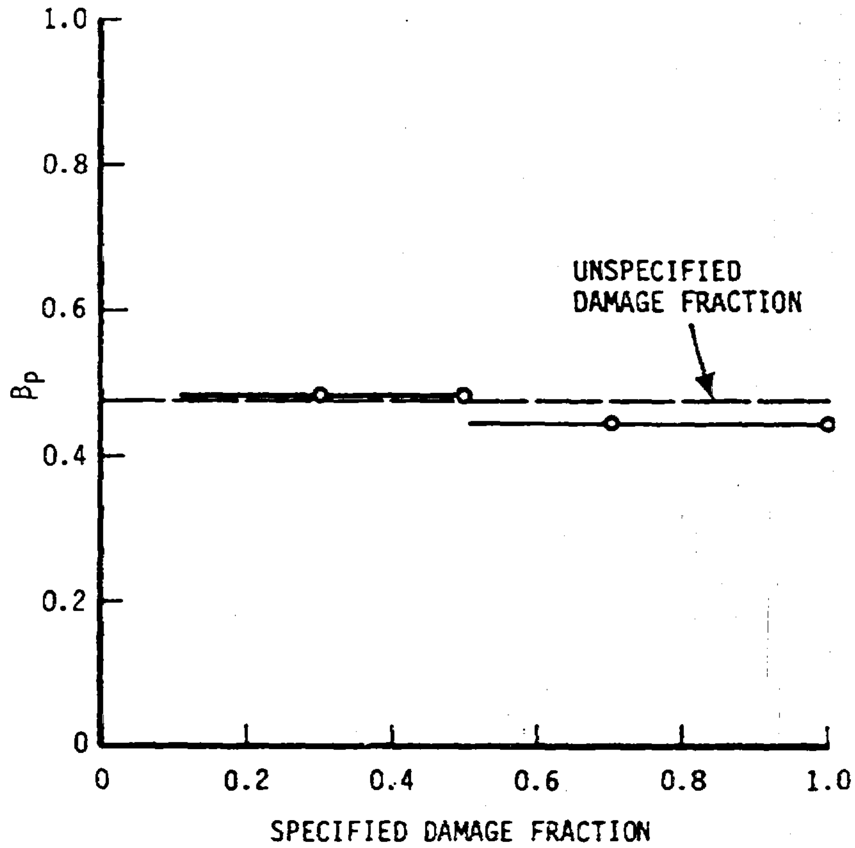


FIGURE 18†

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY WOOD FRAME BUILDINGS

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS QUICKLY

SUPERFICIAL DAMAGE CRITERIA

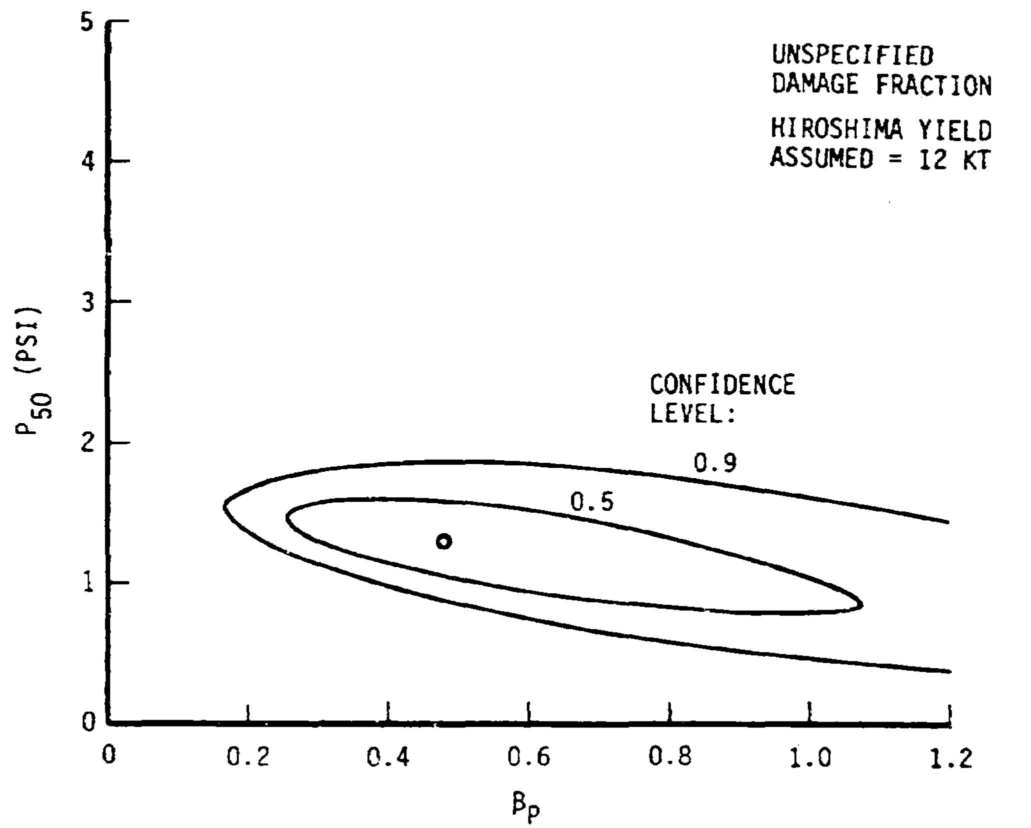


FIGURE 18g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS QUICKLY

SUPERFICIAL DAMAGE CRITERIA

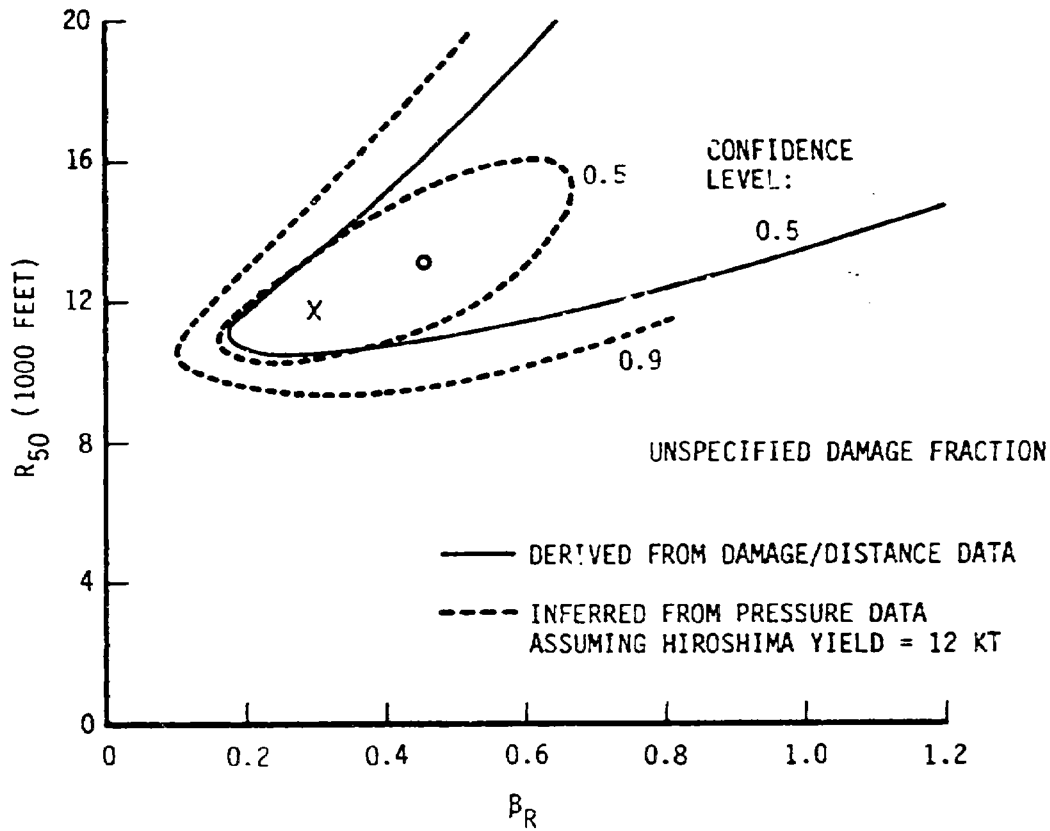


FIGURE 18h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS QUICKLY

SUPERFICIAL DAMAGE CRITERIA

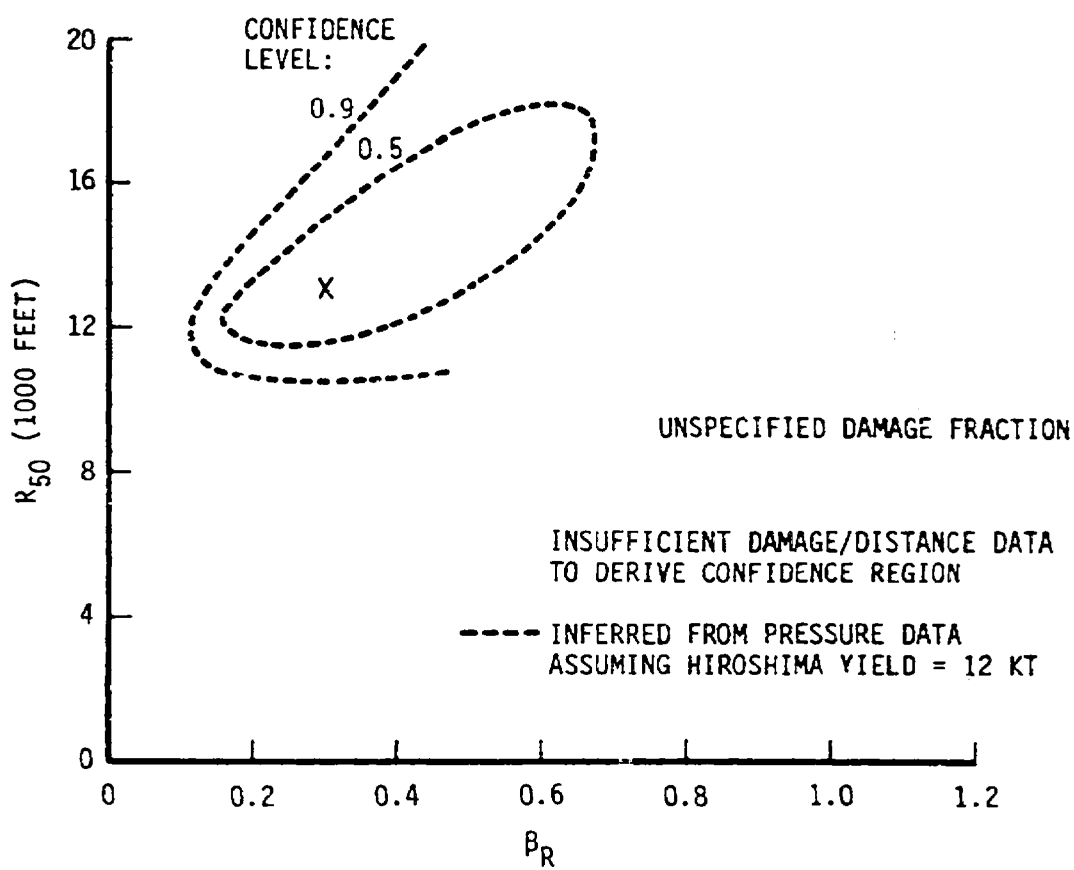


FIGURE 19a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA

WOOD ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

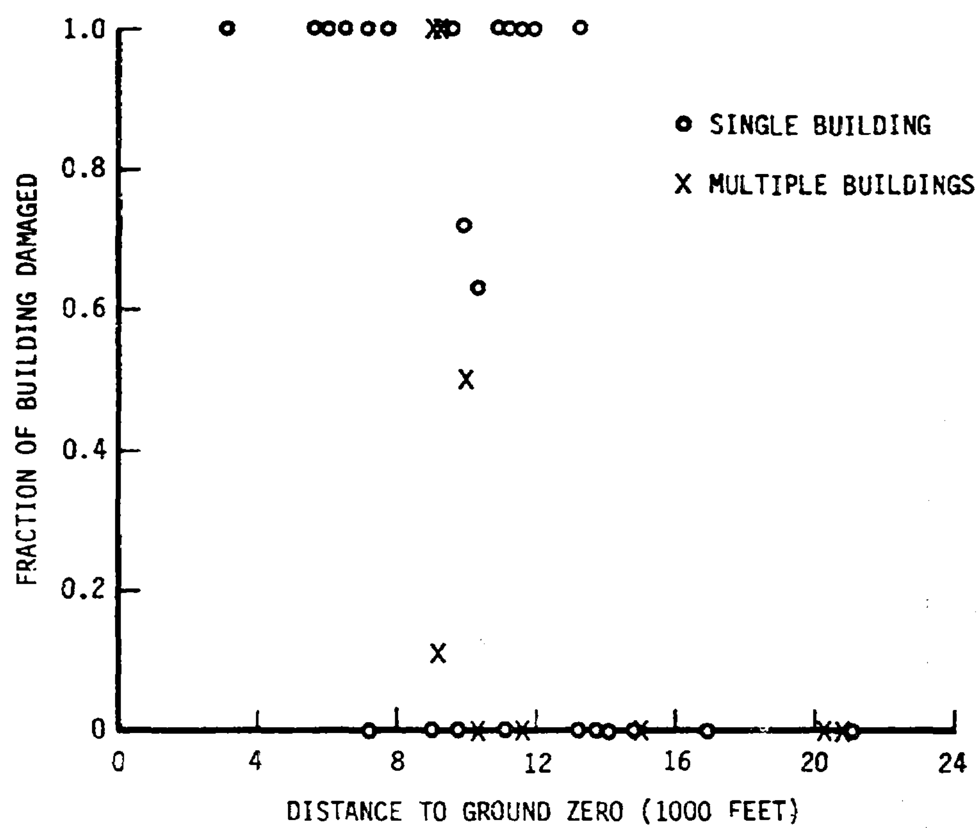


FIGURE 19b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI

WOOD ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

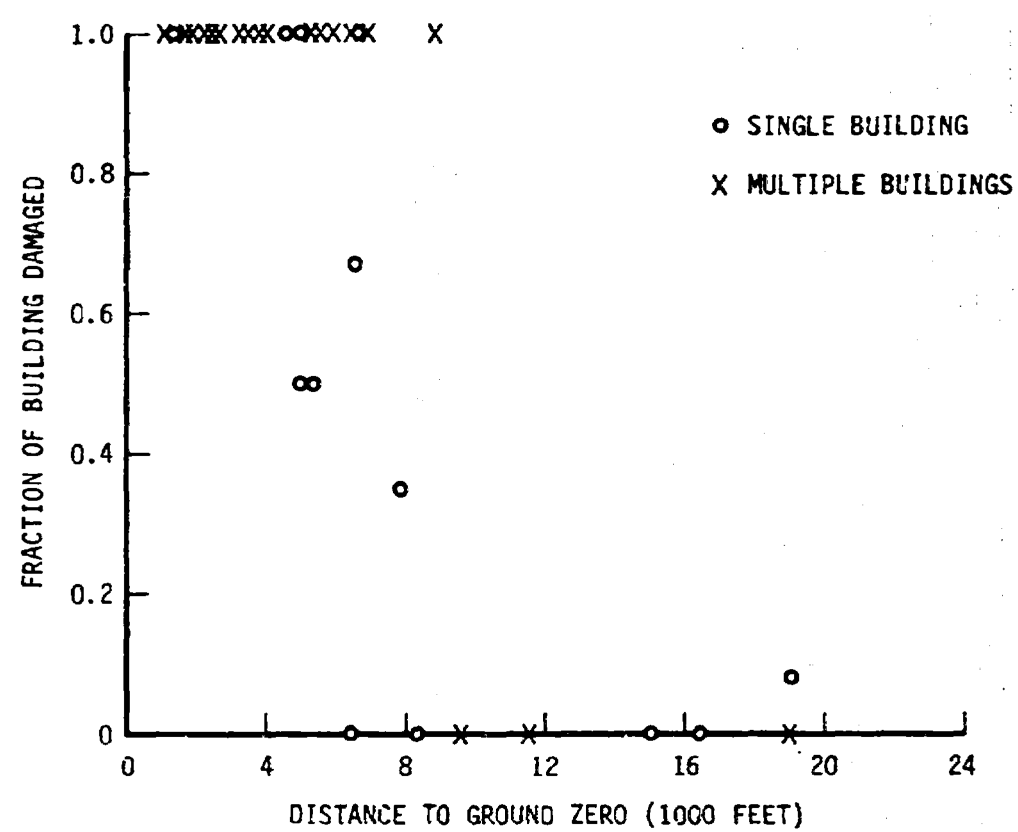


FIGURE 19c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA

WOOD ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

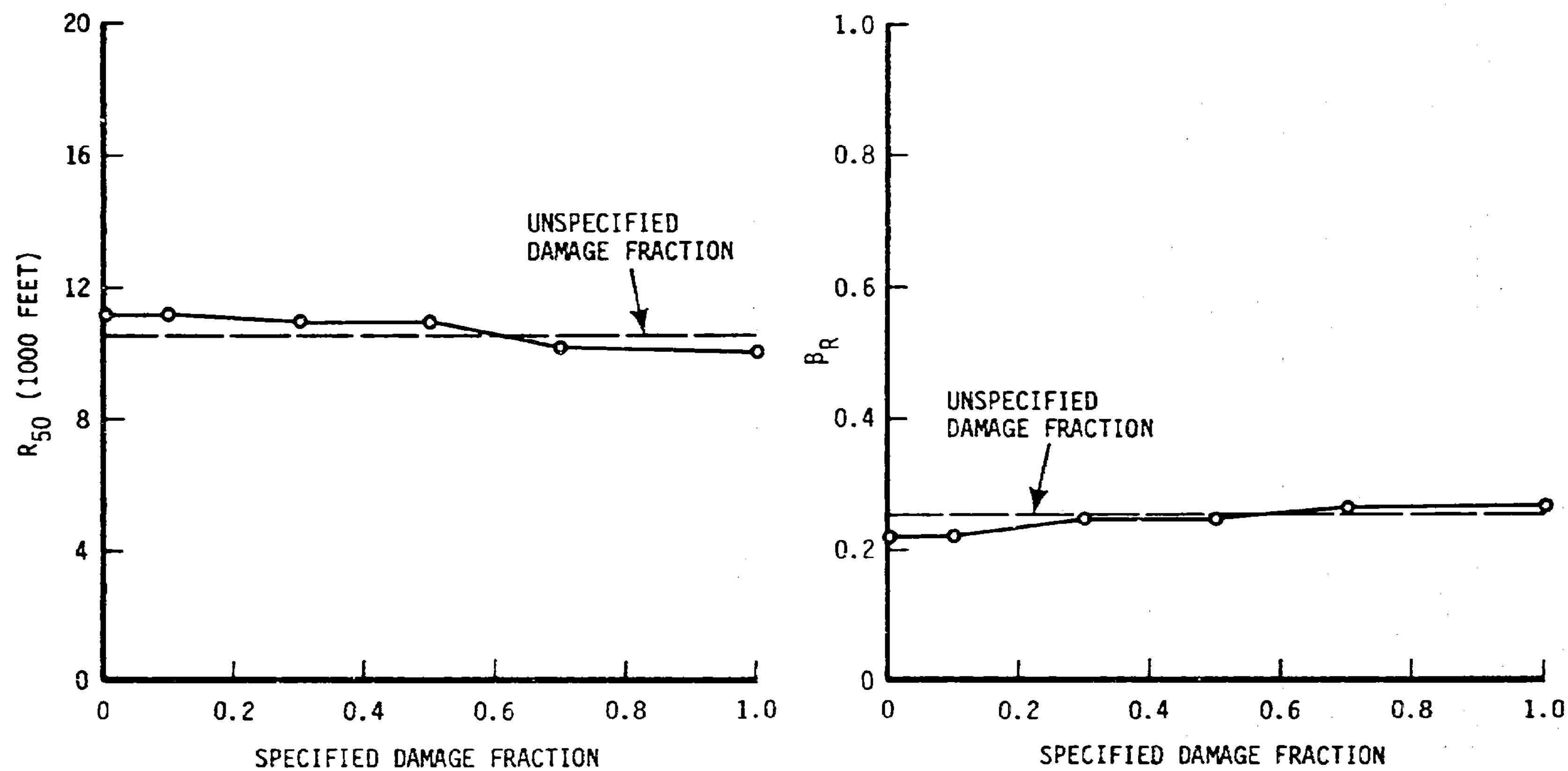


FIGURE 19d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI

WOOD ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

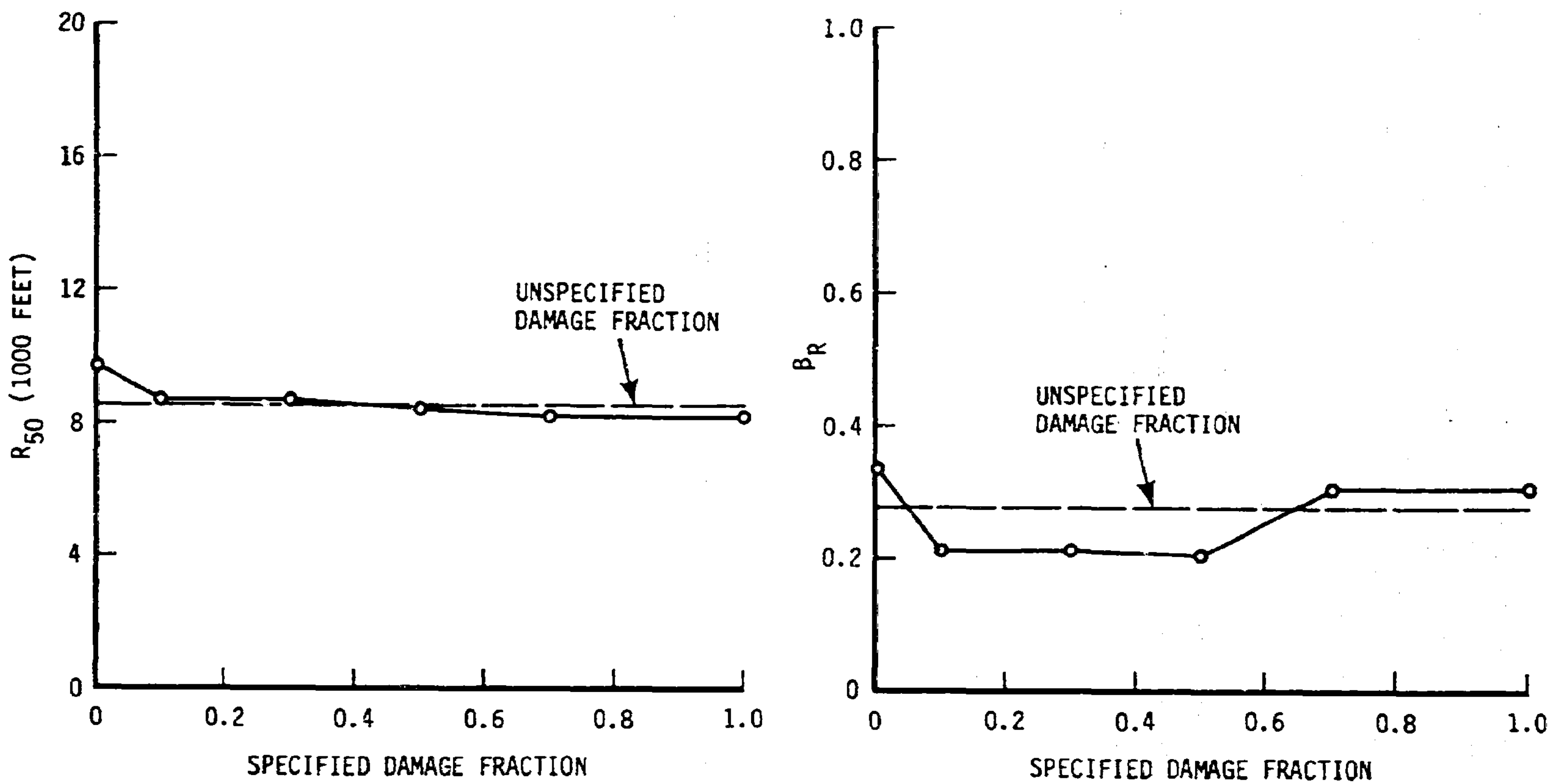


FIGURE 19e

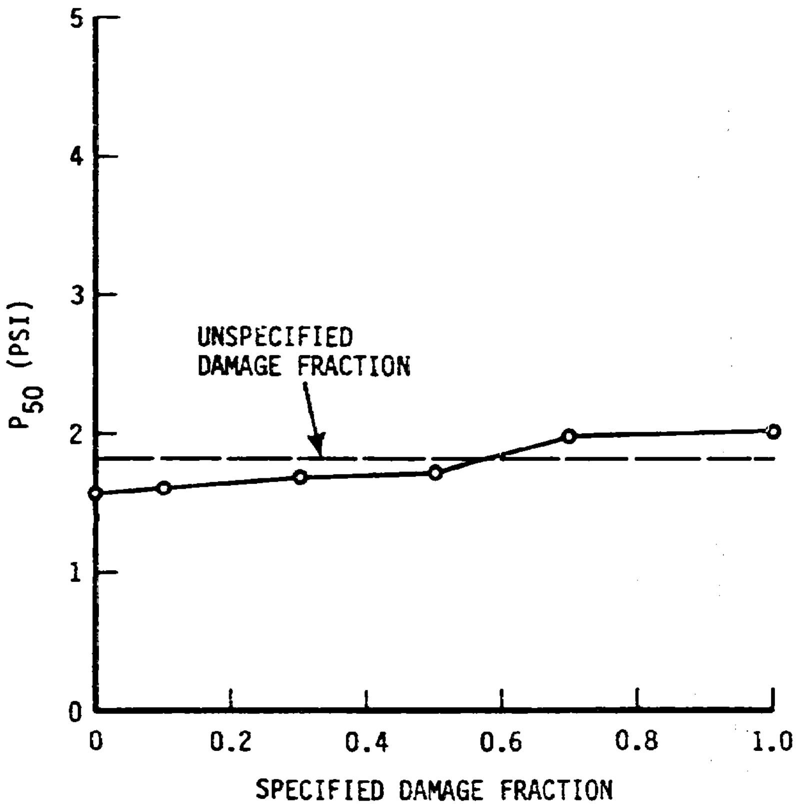
EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

SINGLE-STORY WOOD FRAME BUILDINGS

WOOD ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

HIROSHIMA YIELD ASSUMED = 12 KT



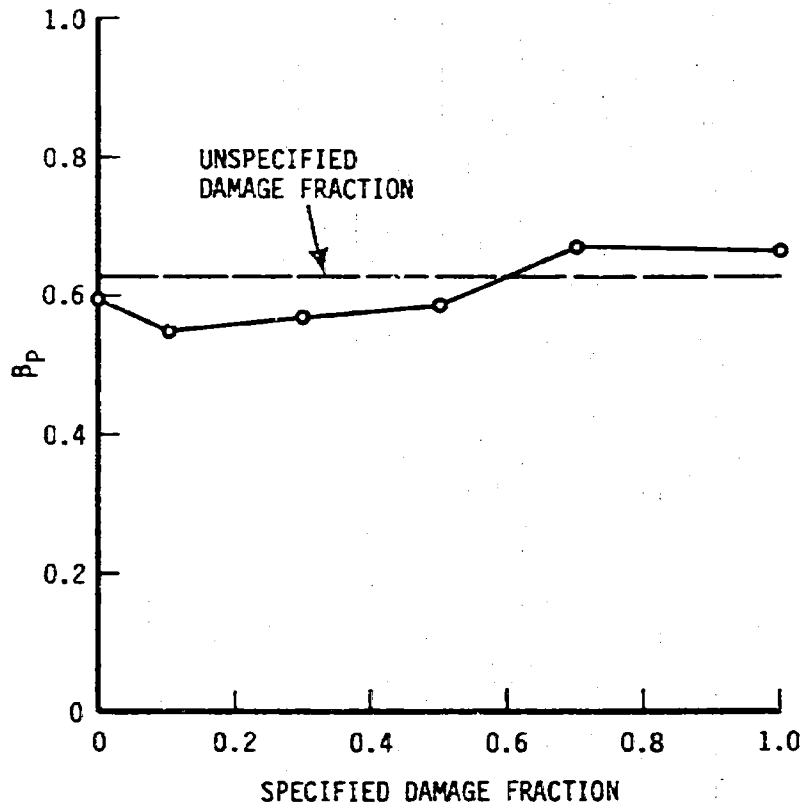


FIGURE 19f

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY WOOD FRAME BUILDINGS

WOOD ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

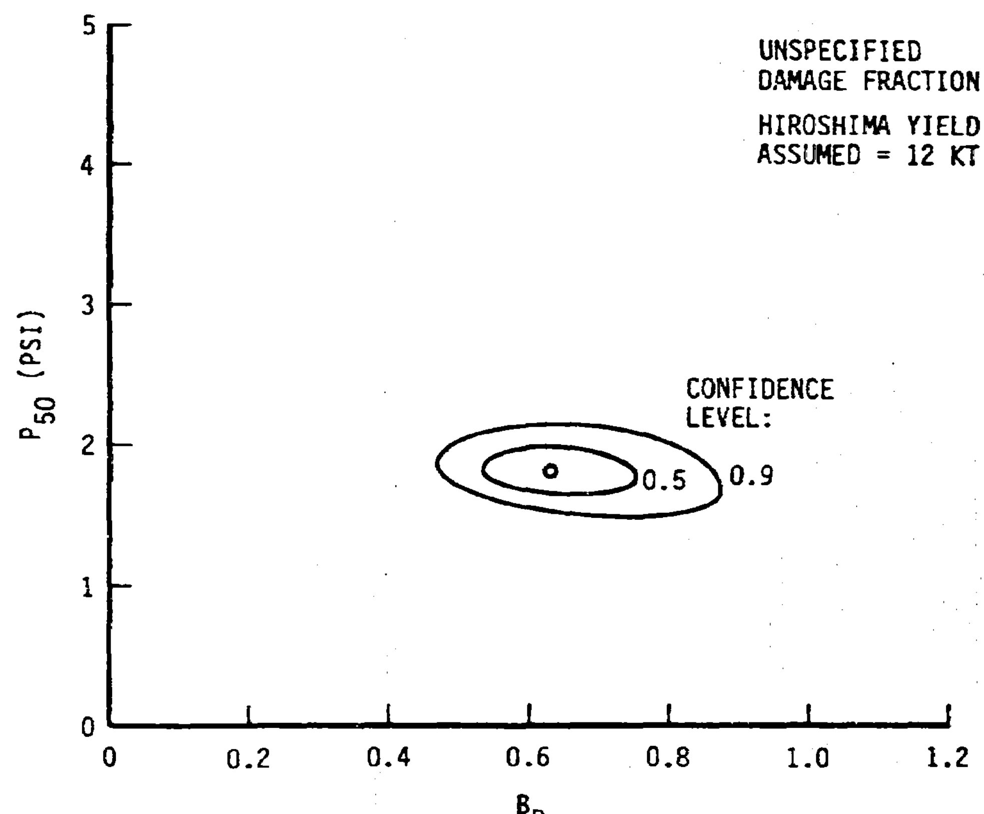


FIGURE 19g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT HIROSHIMA

WOOD ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

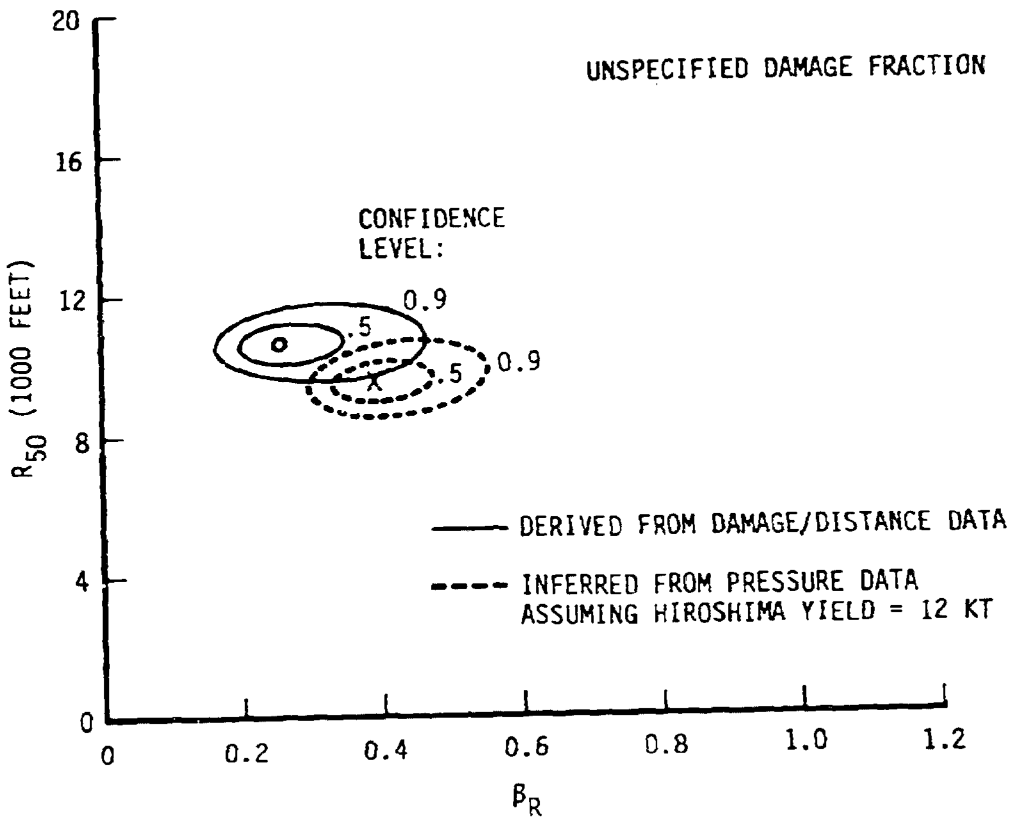


FIGURE 19h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY WOOD FRAME BUILDINGS AT NAGASAKI

WOOD ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

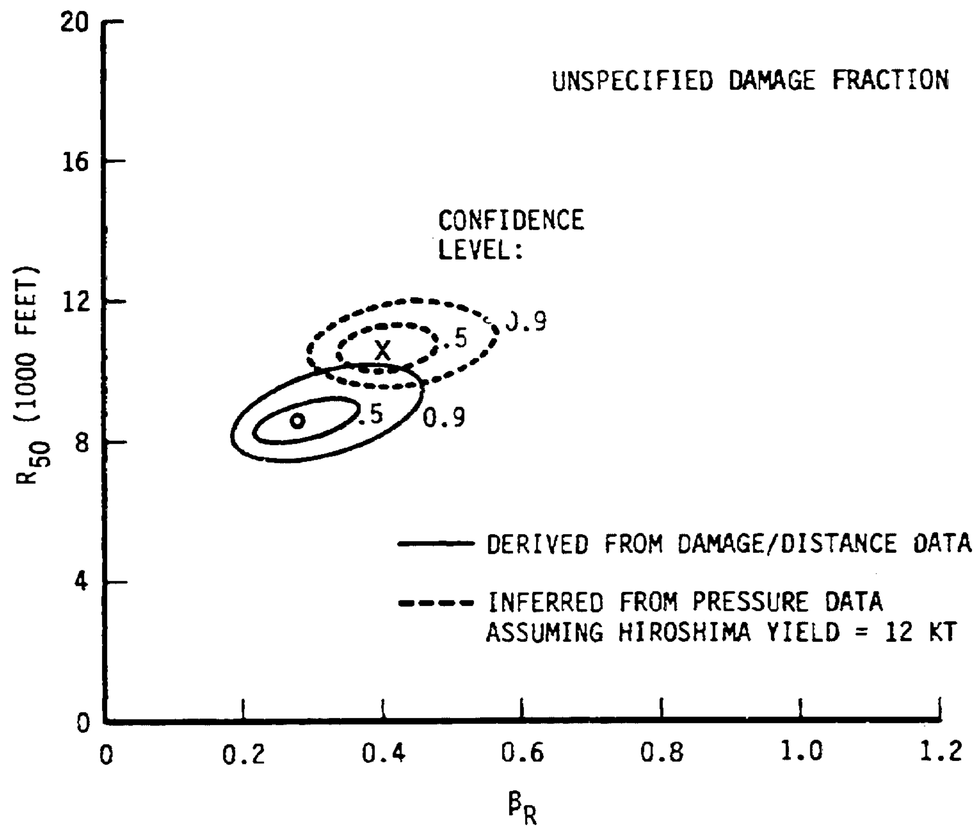


FIGURE 20a

DAMAGE VERSUS DISTANCE DATA

MULTISTORY WOOD FRAME BUILDINGS AT HIROSHIMA

STRUCTURAL DAMAGE CRITERIA

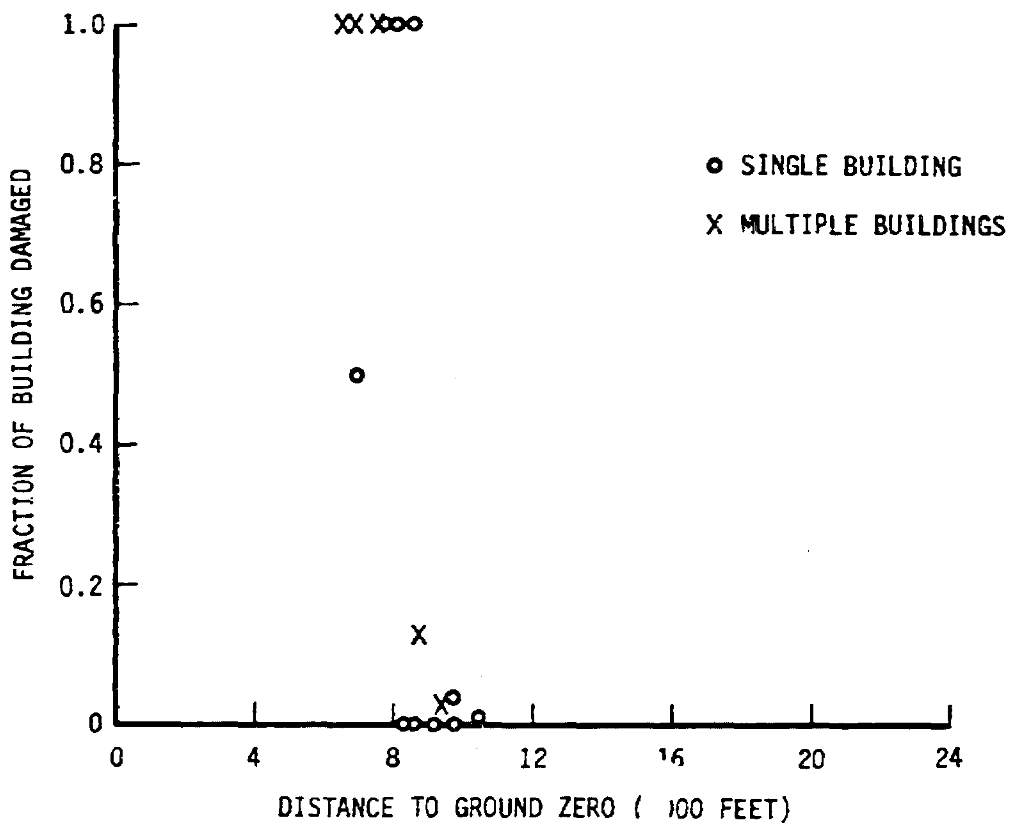


FIGURE 20b

DAMAGE VERSUS DISTANCE DATA

MULTISTORY WOOD FRAME BUILDINGS AT NAGASAKI
STRUCTURAL DAMAGE CRITERIA

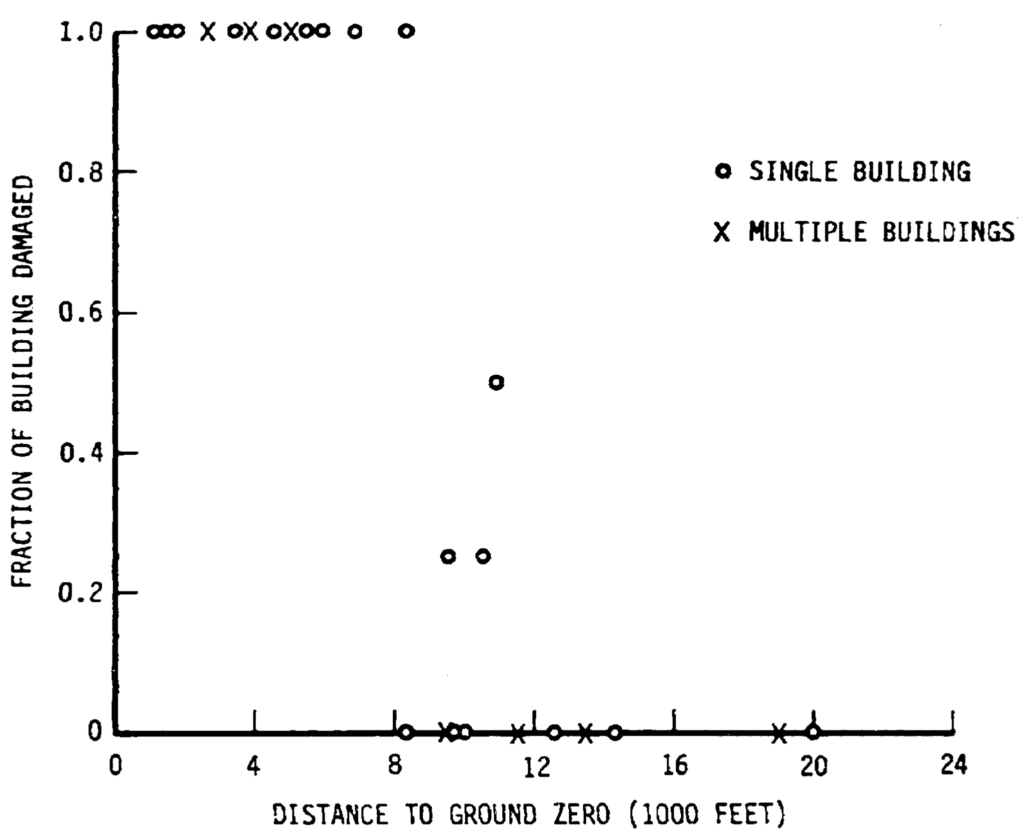
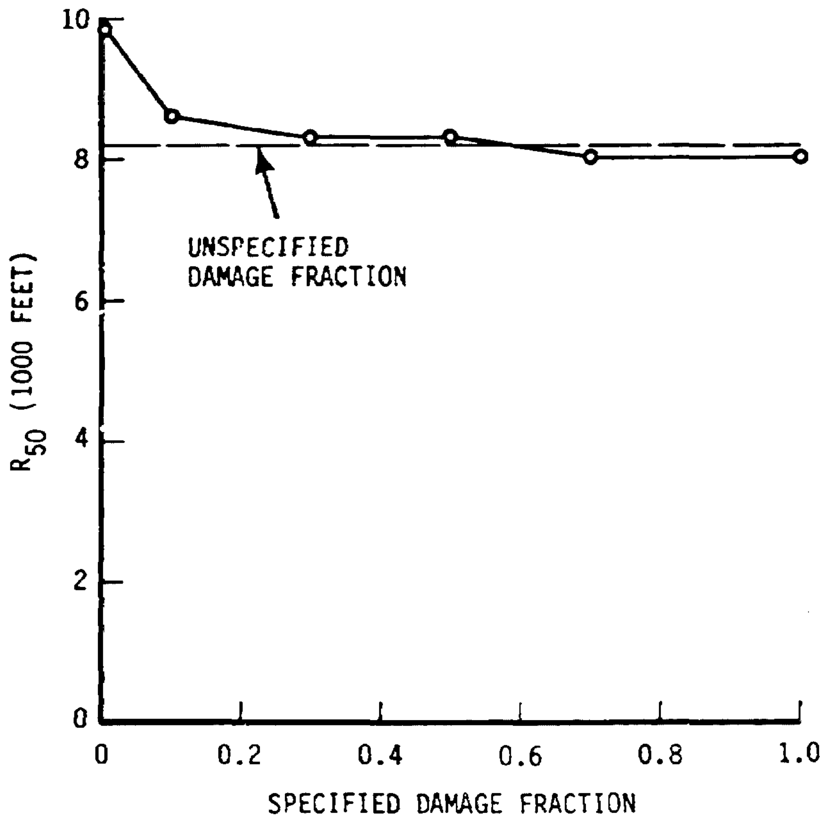


FIGURE 20c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

MULTISTORY WOOD FRAME BUILDINGS AT HIROSHIMA

STRUCTURAL DAMAGE CRITERIA



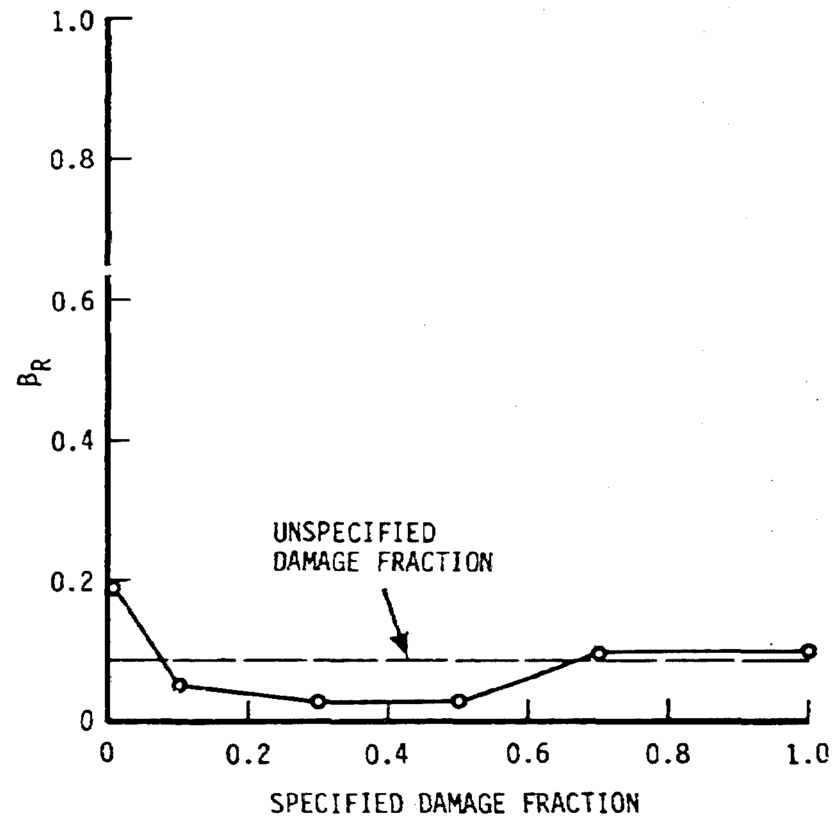


FIGURE 20d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

MULTISTORY WOOD FRAME BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE CRITERIA

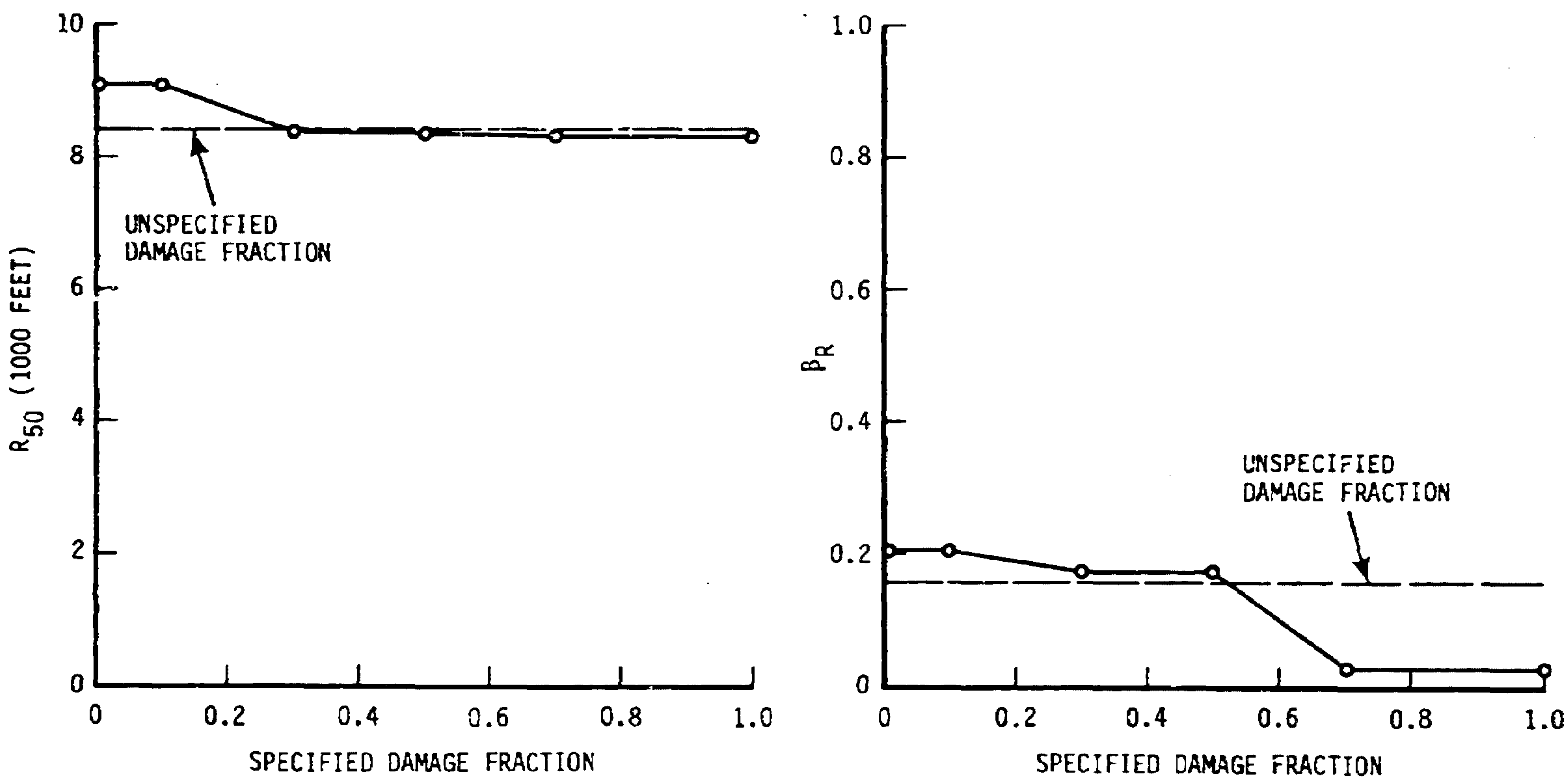
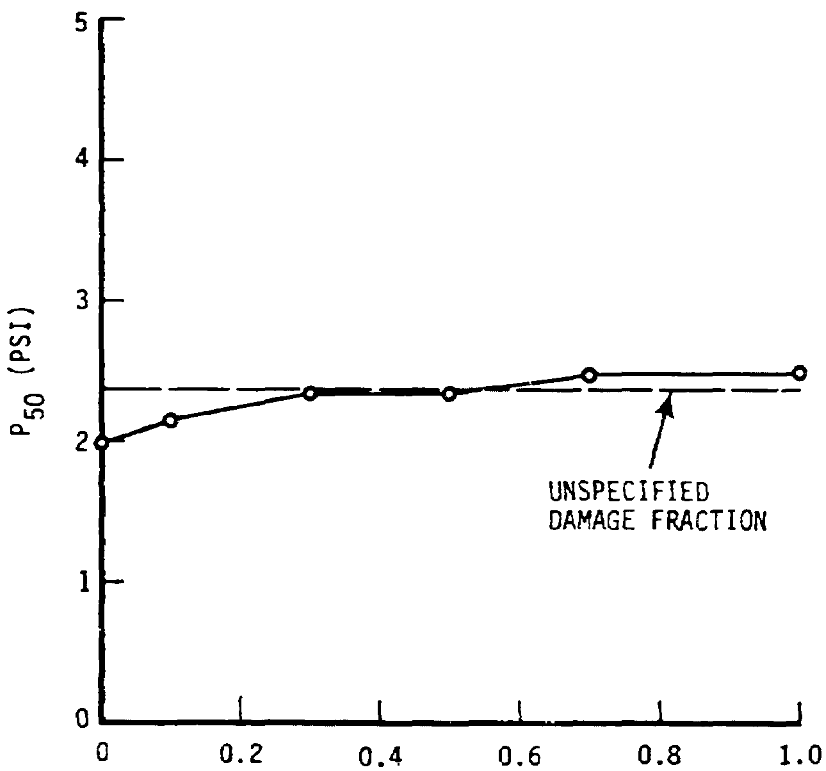


FIGURE 20e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

MULTISTORY WOOD FRAME BUILDINGS
STRUCTURAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT



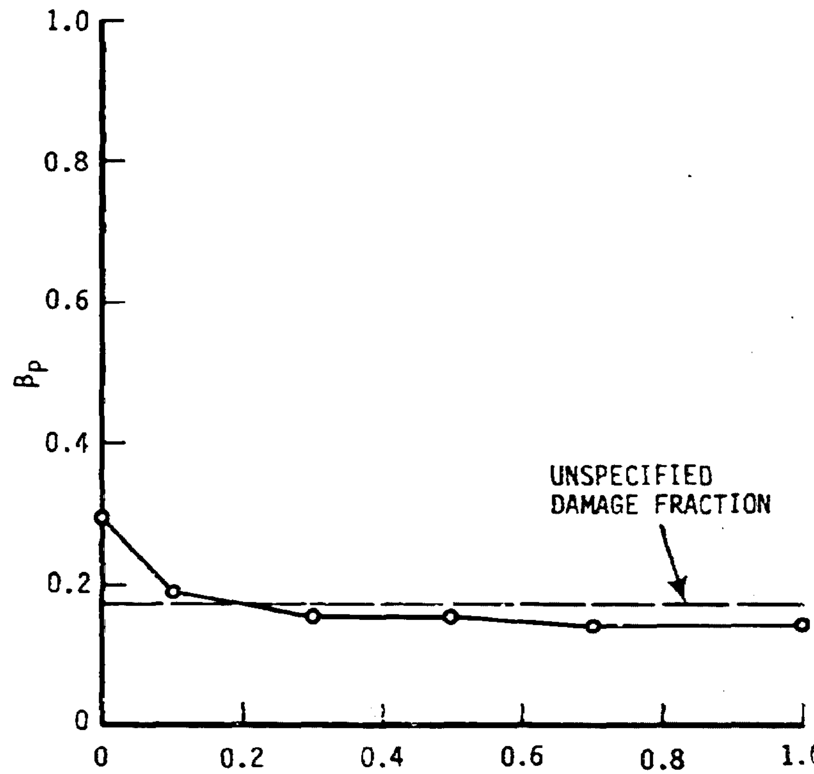


FIGURE 20f

CONFIDENCE REGIONS FOR P_{50} AND β_P

MULTISTORY WOOD FRAME BUILDINGS

STRUCTURAL DAMAGE CRITERIA

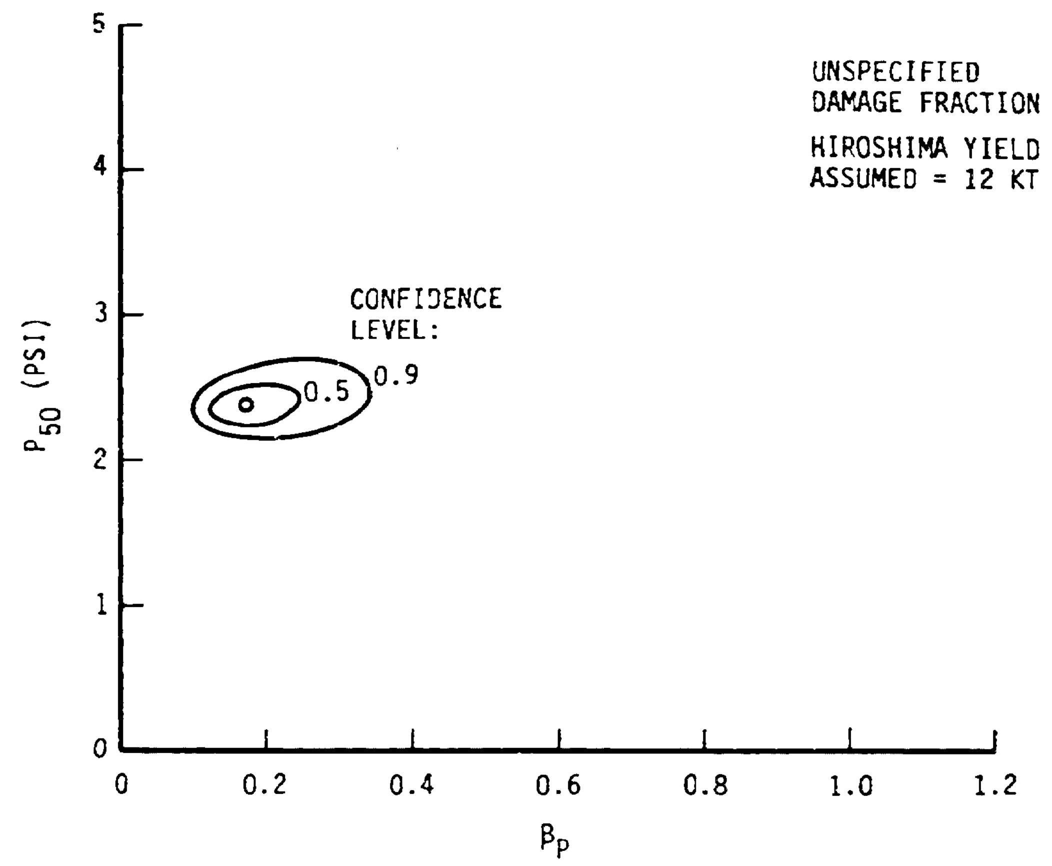


FIGURE 20g

CONFIDENCE REGIONS FOR R_{50} AND β_R

MULTISTORY WOOD FRAME BUILDINGS AT HIROSHIMA
STRUCTURAL DAMAGE CRITERIA

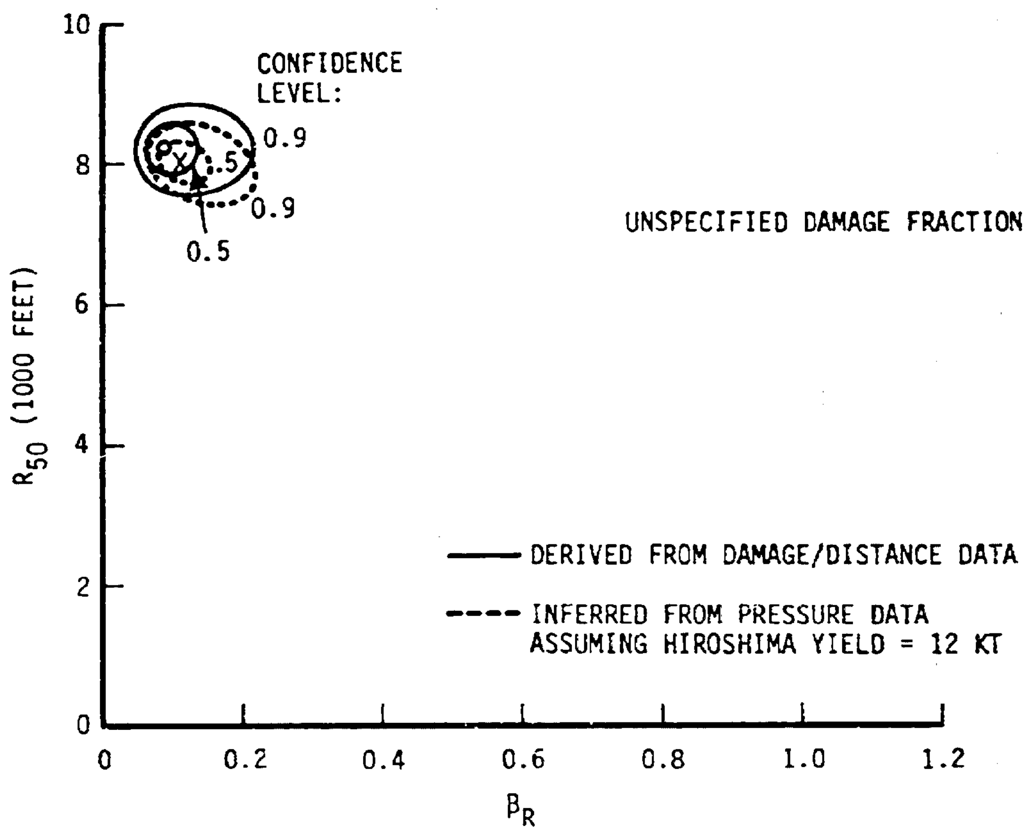


FIGURE 20h

CONFIDENCE REGIONS FOR R_{50} AND B_R

MULTISTORY WOOD FRAME BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE CRITERIA

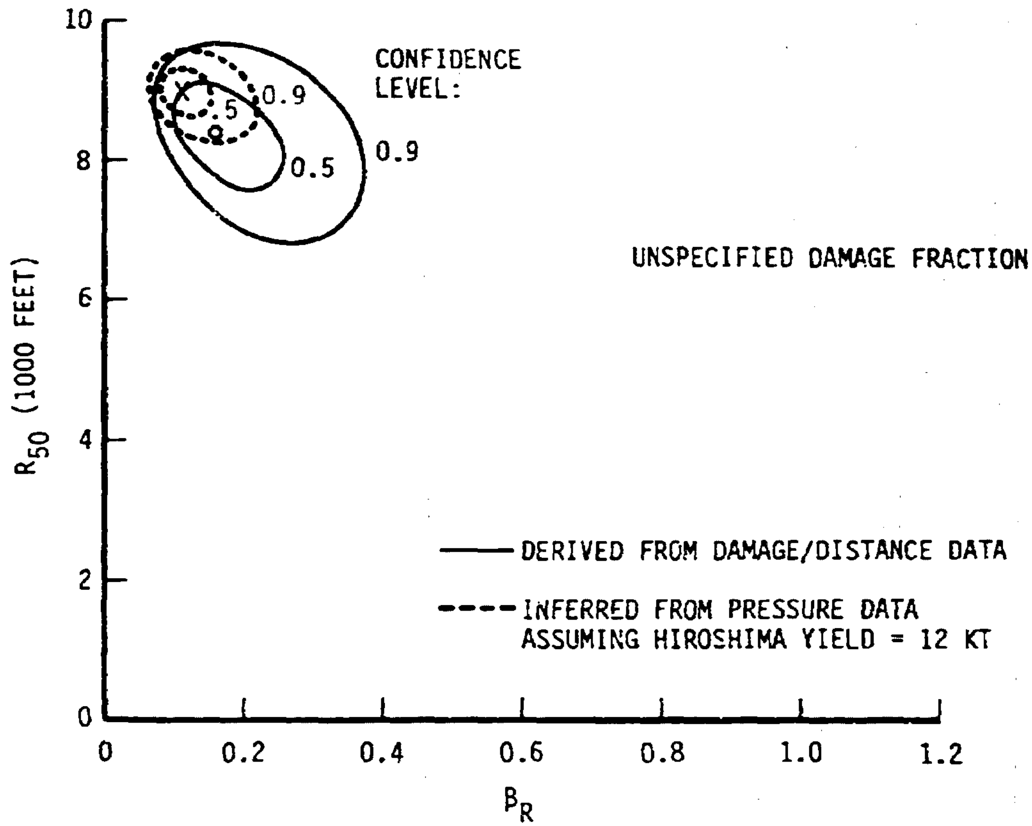


FIGURE 21a

DAMAGE VERSUS DISTANCE DATA

MULTISTORY WOOD FRAME BUILDINGS AT HIROSHIMA
WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY
STRUCTURAL DAMAGE CRITERIA

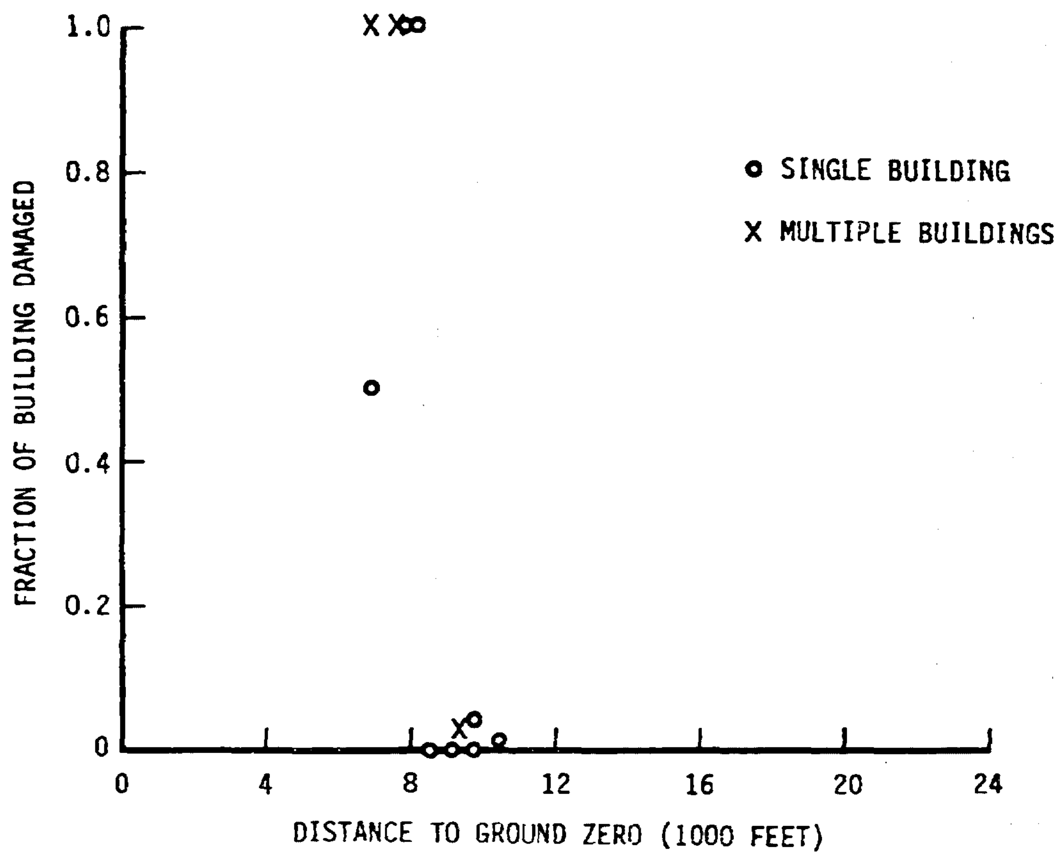


FIGURE 21b

DAMAGE VERSUS DISTANCE DATA

MULTISTORY WOOD FRAME BUILDINGS AT NAGASAKI
WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY
STRUCTURAL DAMAGE CRITERIA

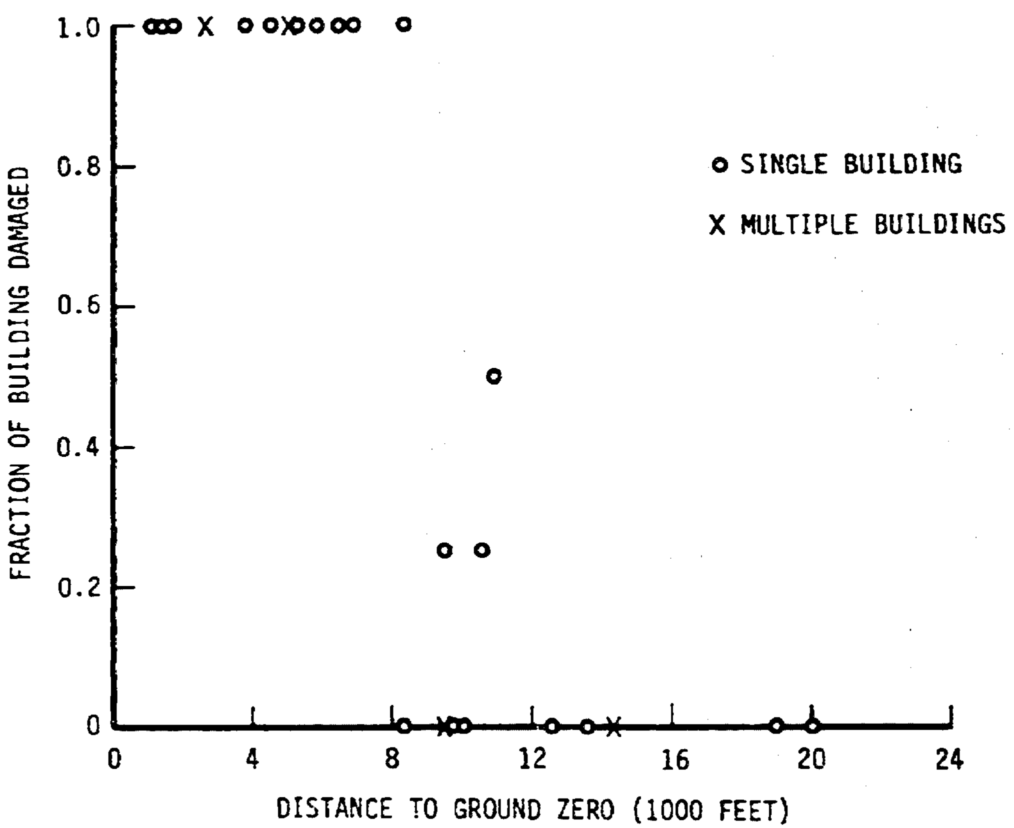


FIGURE 21c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

MULTISTORY WOOD FRAME BUILDINGS AT HIROSHIMA

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE CRITERIA

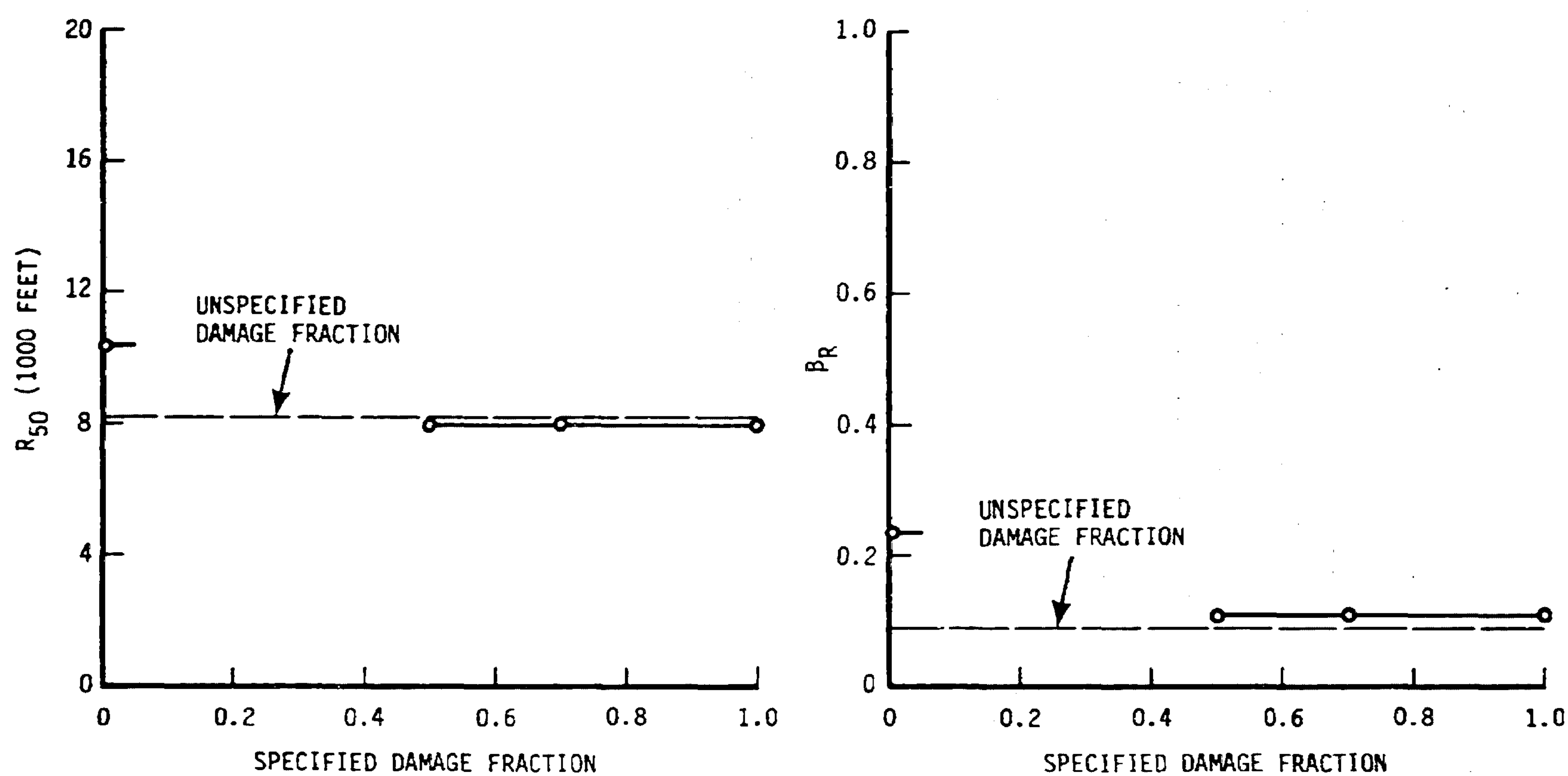


FIGURE 21d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

MULTISTORY WOOD FRAME BUILDINGS AT NAGASAKI

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE CRITERIA

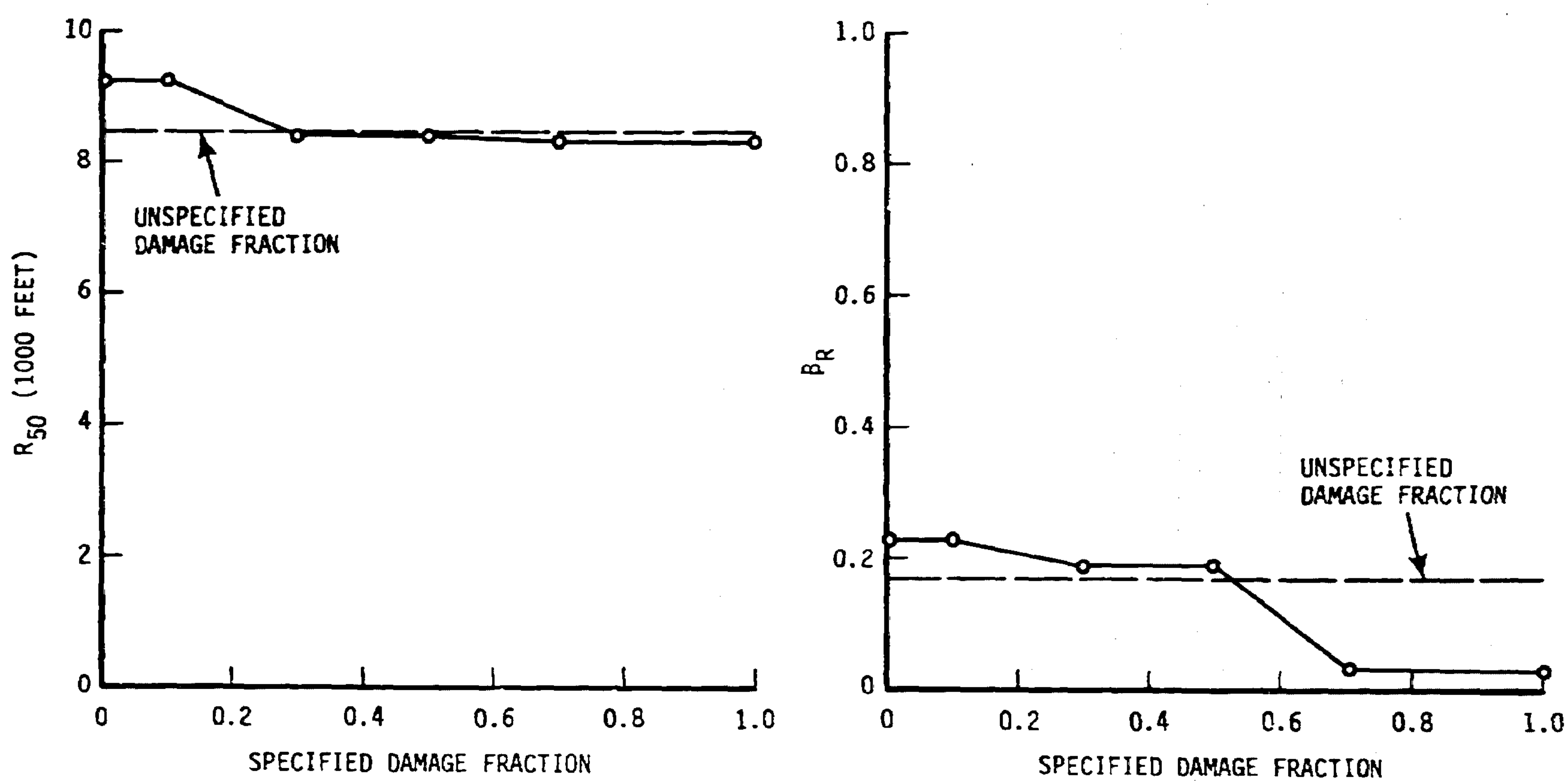


FIGURE 21e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

MULTISTORY WOOD FRAME BUILDINGS

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT

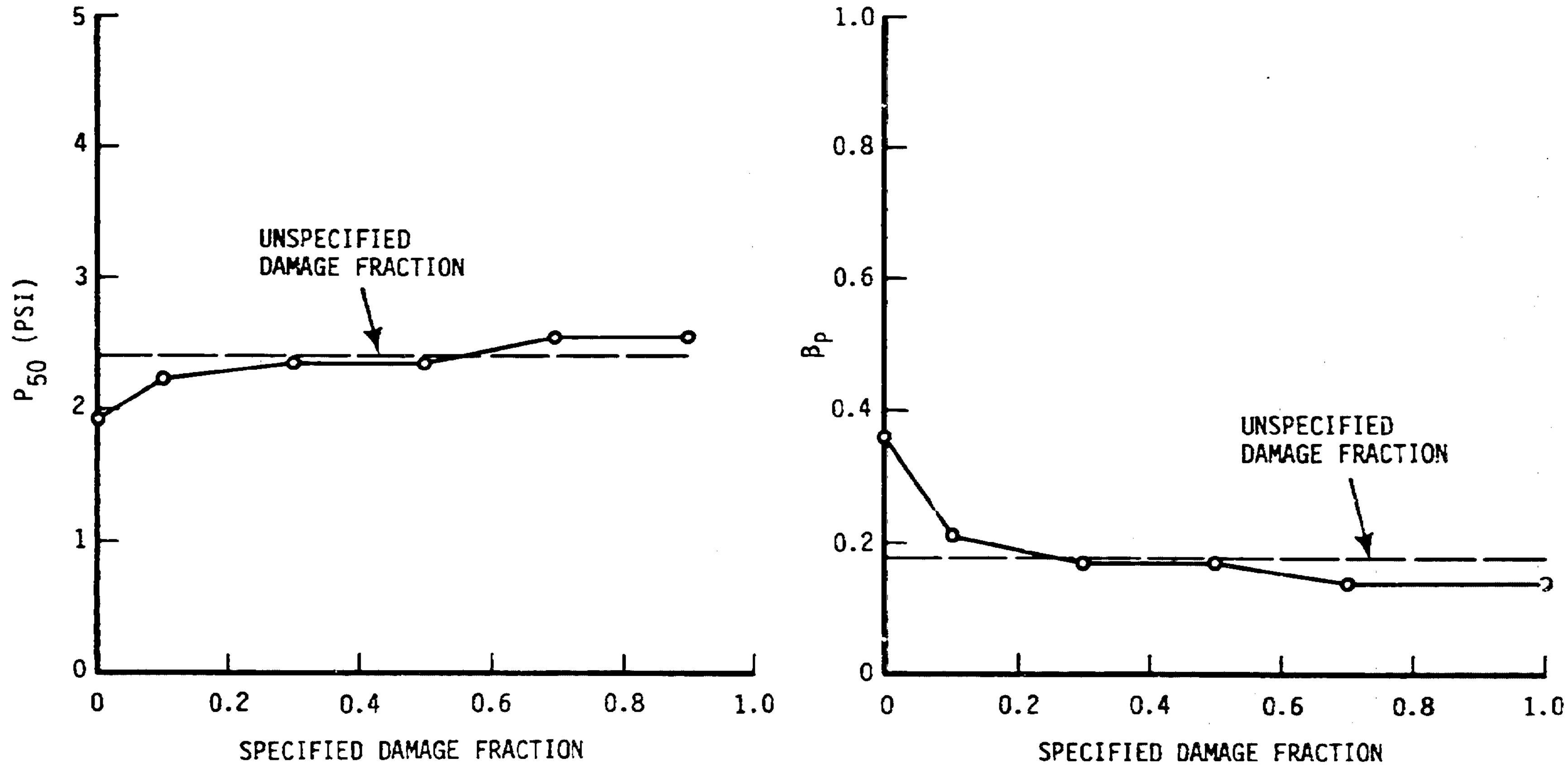


FIGURE 21f

CONFIDENCE REGIONS FOR P_{50} AND β_p

MULTISTORY WOOD FRAME BUILDINGS

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE CRITERIA

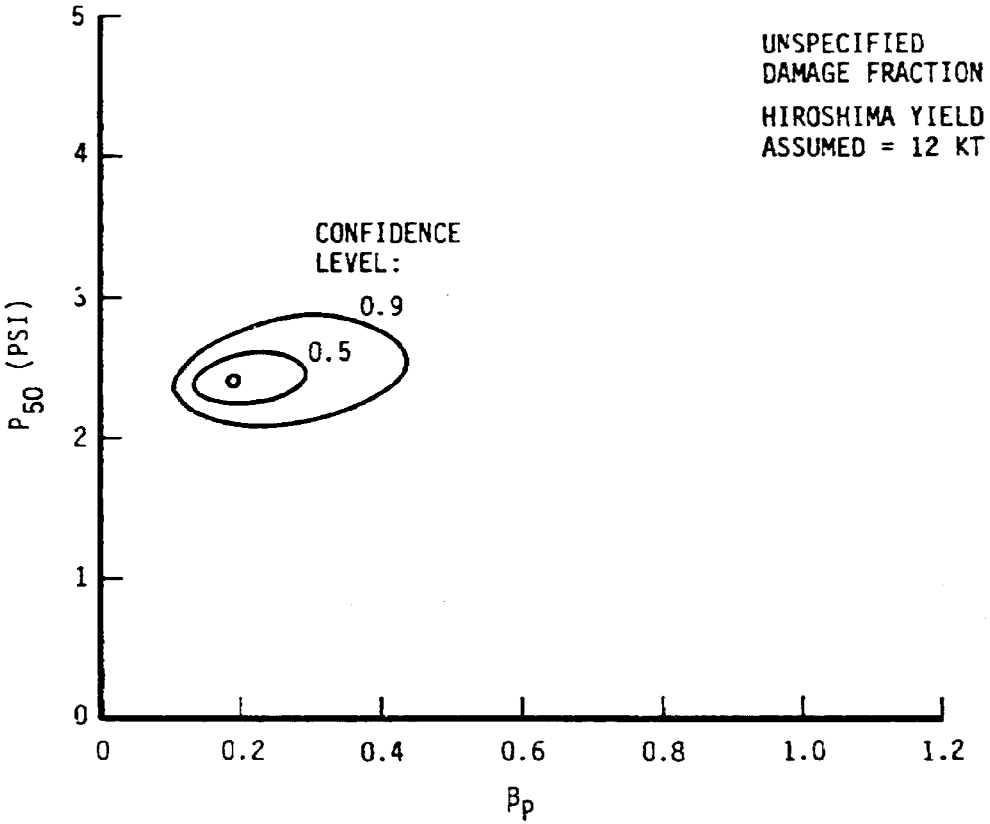


FIGURE 21g

CONFIDENCE REGIONS FOR R_{50} AND β_R

MULTISTORY WOOD FRAME BUILDINGS AT HIROSHIMA

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE CRITERIA

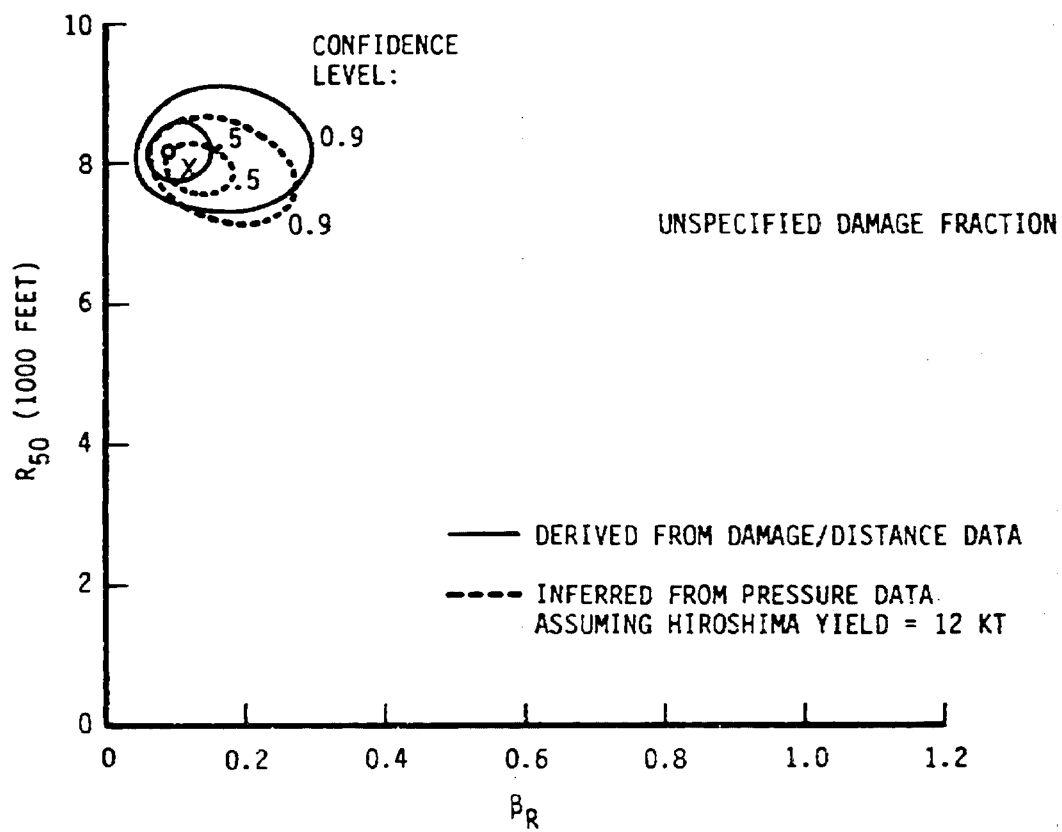


FIGURE 21h

CONFIDENCE REGIONS FOR R_{50} AND β_R

MULTISTORY WOOD FRAME BUILDINGS AT NAGASAKI

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE CRITERIA

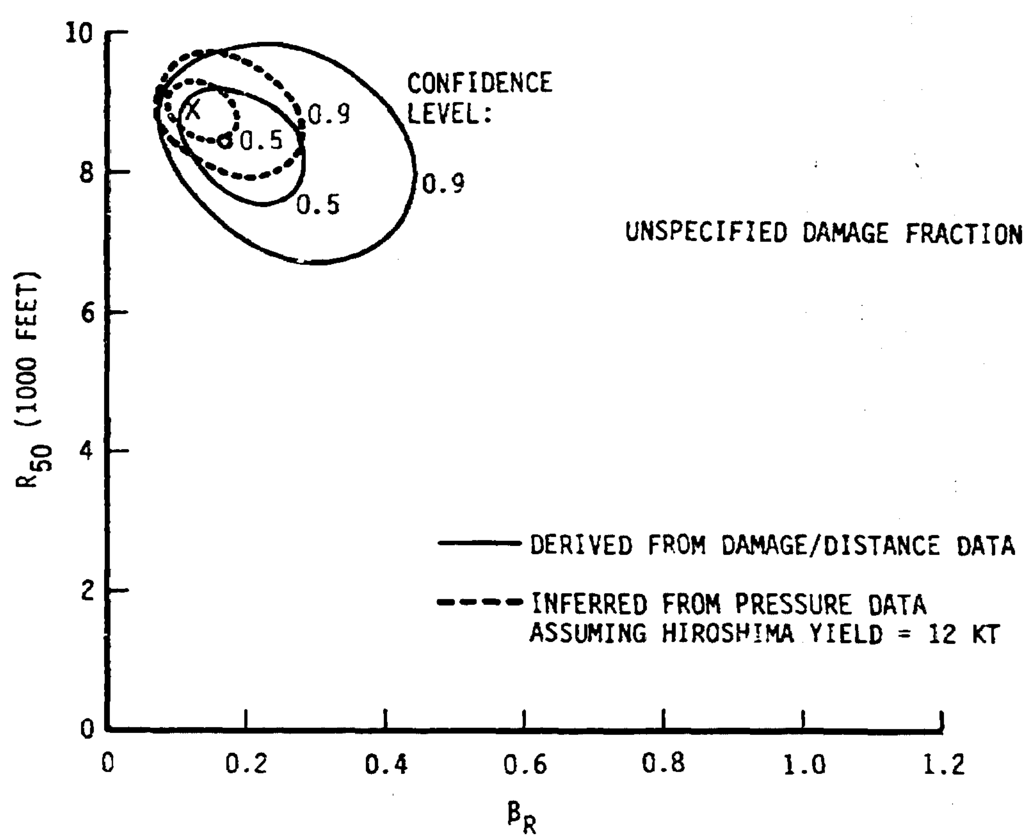


FIGURE 22a

DAMAGE VERSUS DISTANCE DATA

MULTISTORY WOOD FRAME BUILDINGS AT HIROSHIMA

SUPERFICIAL DAMAGE CRITERIA

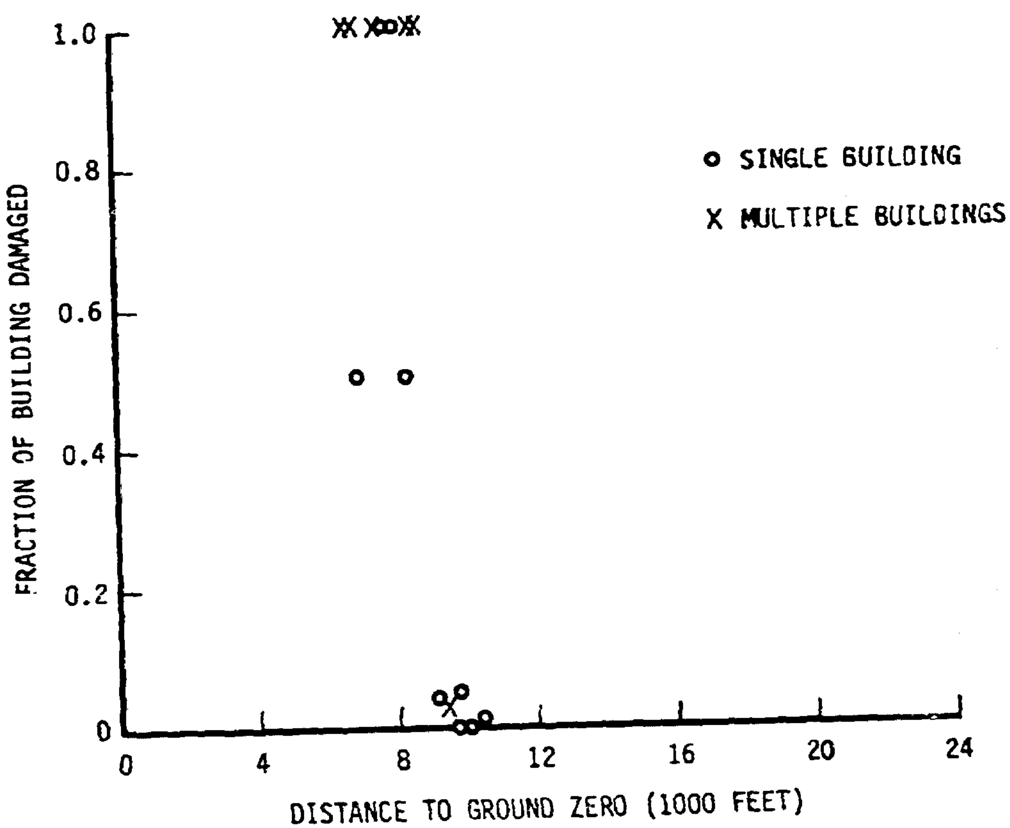


FIGURE 22b

DAMAGE VERSUS DISTANCE DATA

MULTISTORY WOOD FRAME BUILDINGS AT NAGASAKI
SUPERFICIAL DAMAGE CRITERIA

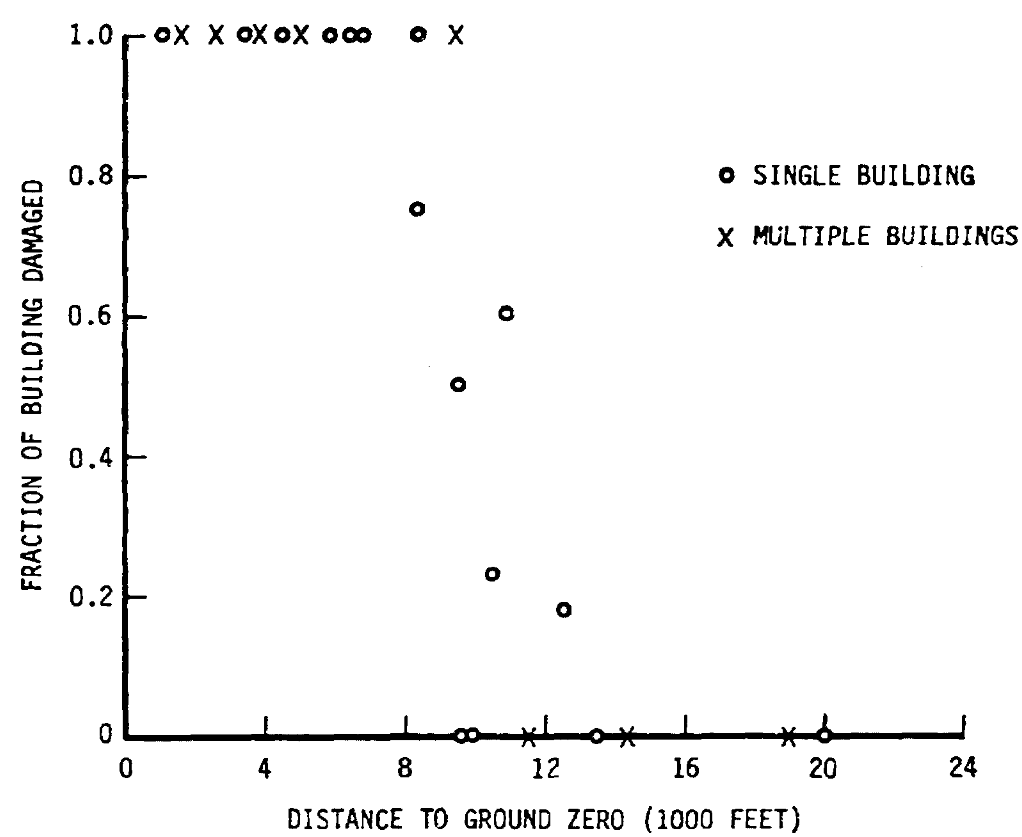


FIGURE 22c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

MULTISTORY WOOD FRAME BUILDINGS AT HIROSHIMA

SUPERFICIAL DAMAGE CRITERIA

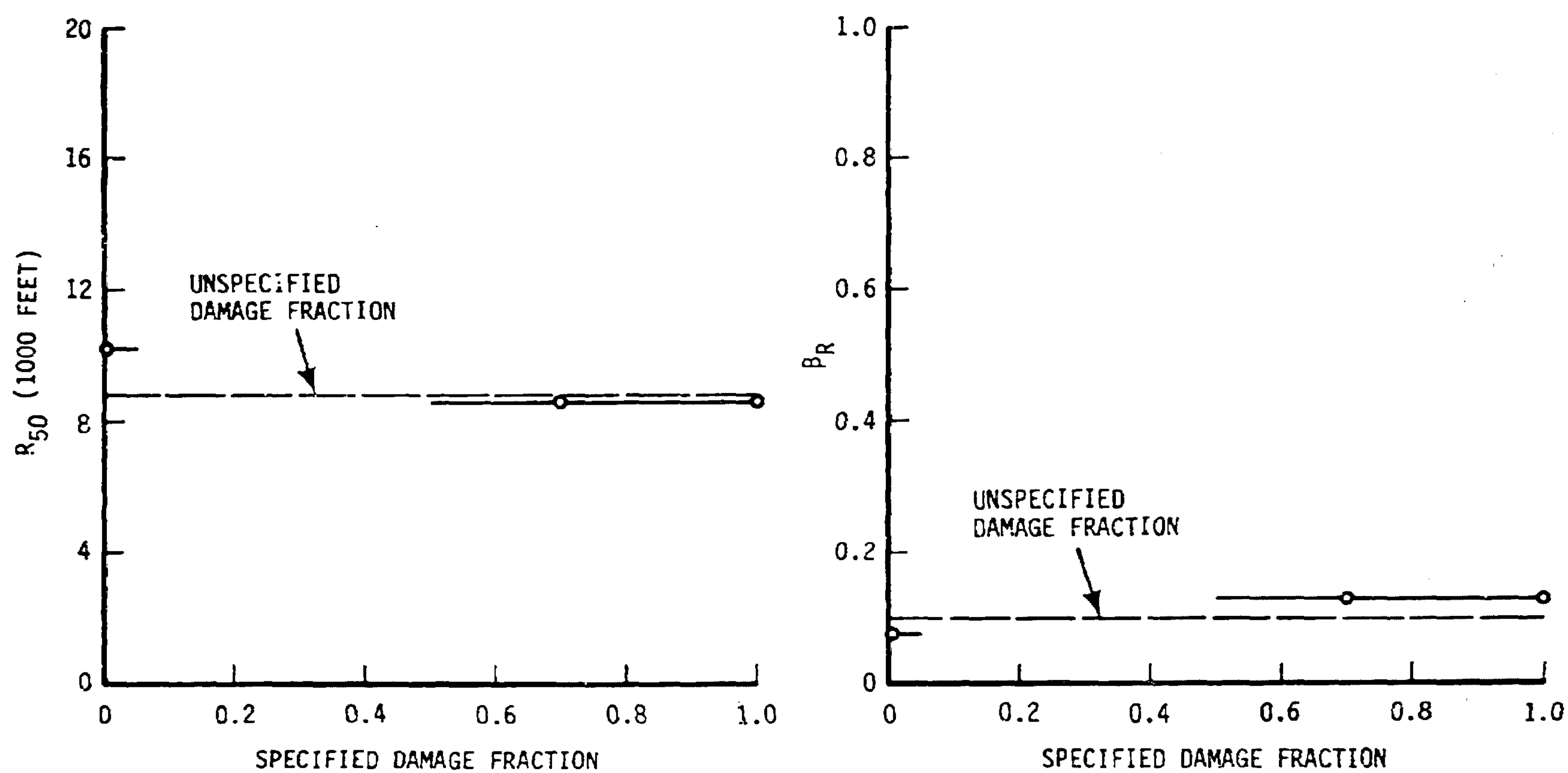
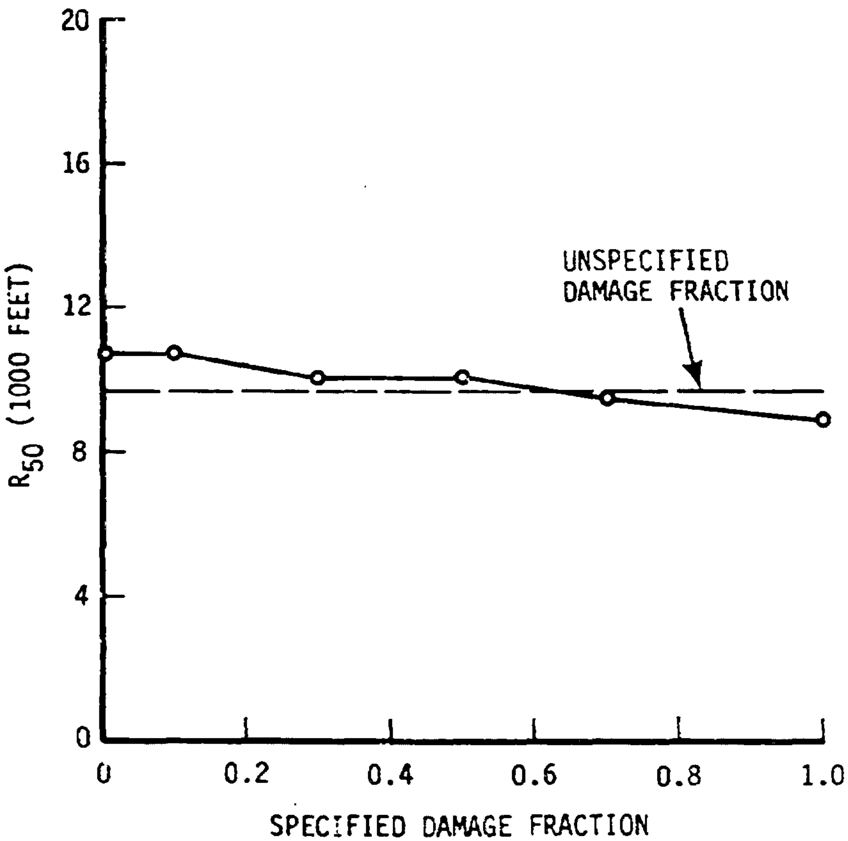


FIGURE 22d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND B_R

MULTISTORY WOOD FRAME BUILDINGS AT NAGASAKI

SUPERFICIAL DAMAGE CRITERIA



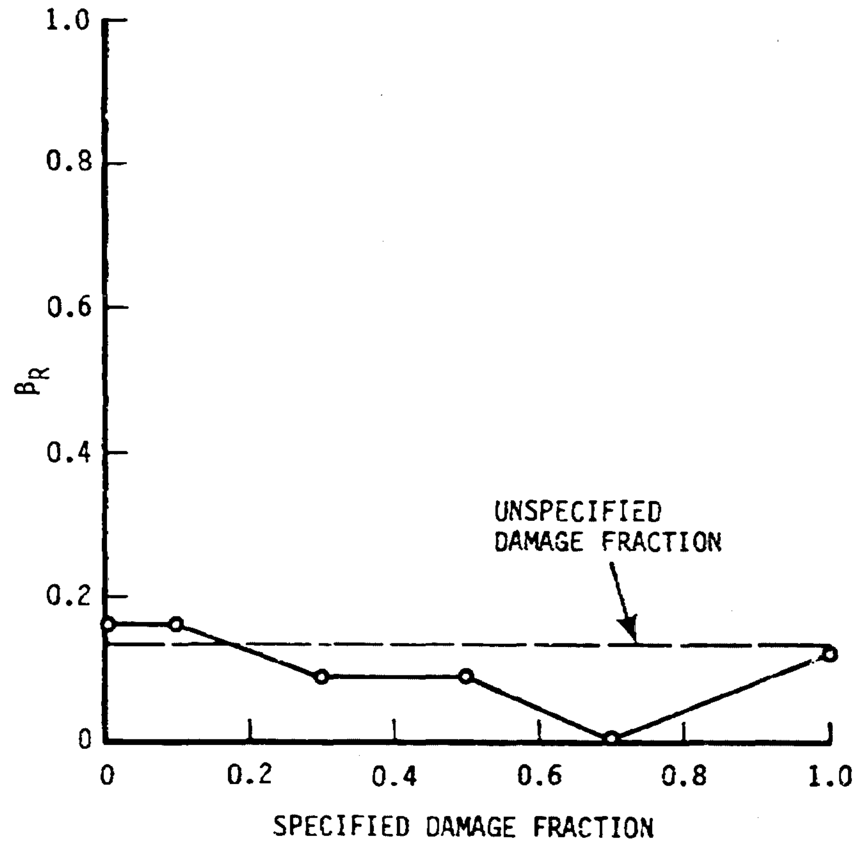


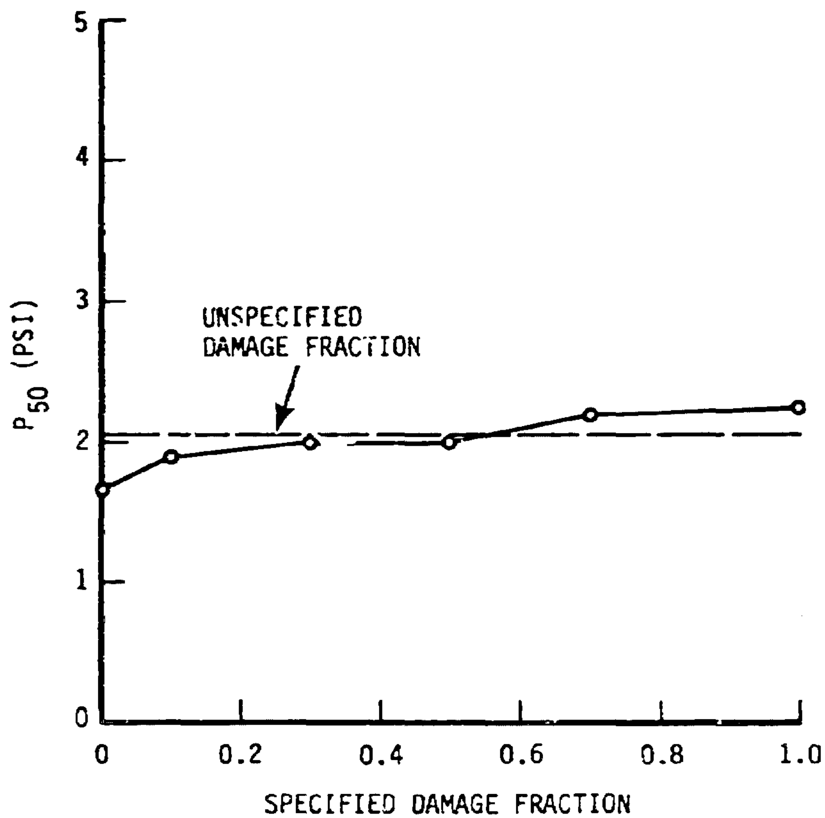
FIGURE 22e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

MULTISTORY WOOD FRAME BUILDINGS

SUPERFICIAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT



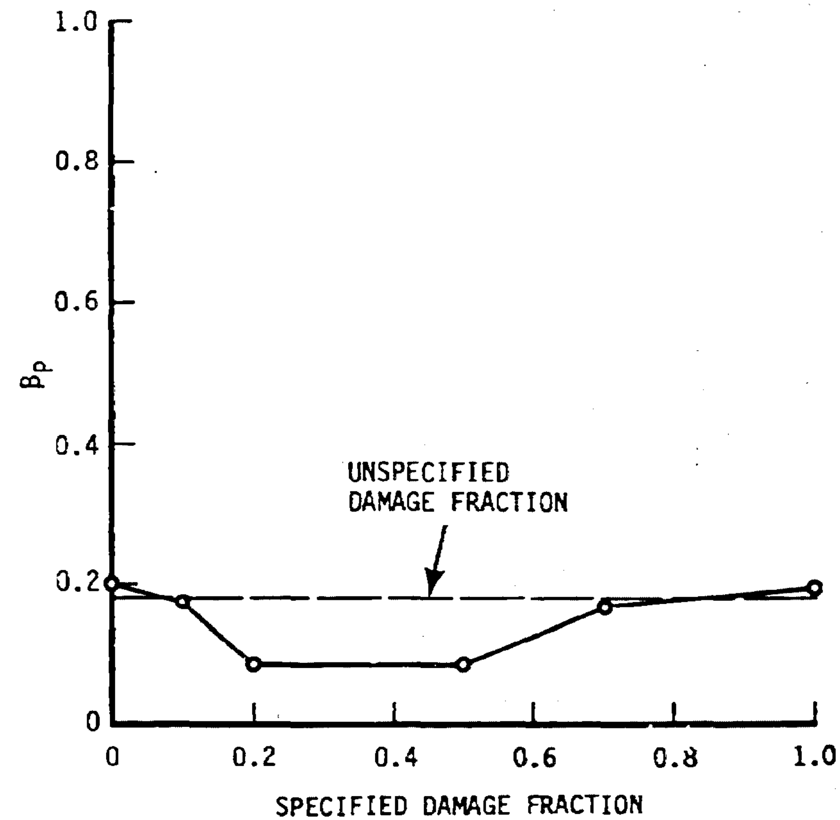


FIGURE 22f

CONFIDENCE REGIONS FOR P_{50} AND β_P

MULTISTORY WOOD FRAME BUILDINGS

SUPERFICIAL DAMAGE CRITERIA

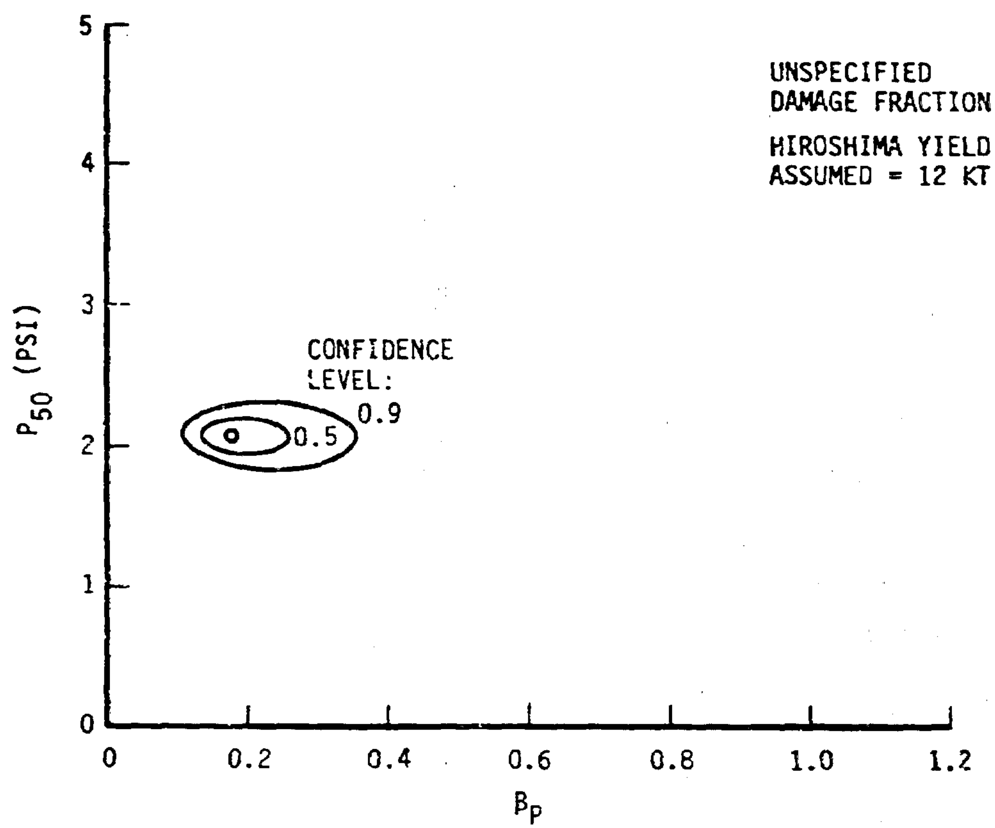


FIGURE 22g

CONFIDENCE REGIONS FOR R_{50} AND β_R

MULTISTORY WOOD FRAME BUILDINGS AT HIROSHIMA
SUPERFICIAL DAMAGE CRITERIA

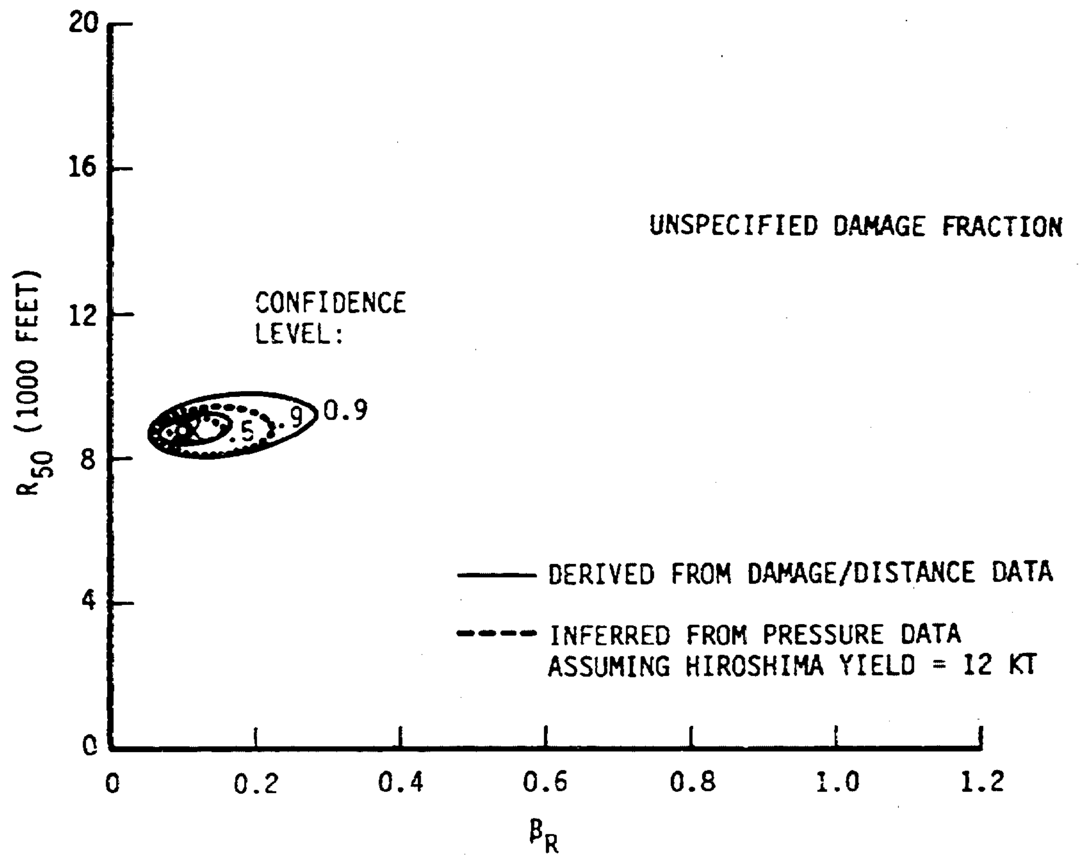


FIGURE 22h

CONFIDENCE REGIONS FOR R_{50} AND β_R

MULTISTORY WOOD FRAME BUILDINGS AT NAGASAKI
SUPERFICIAL DAMAGE CRITERIA

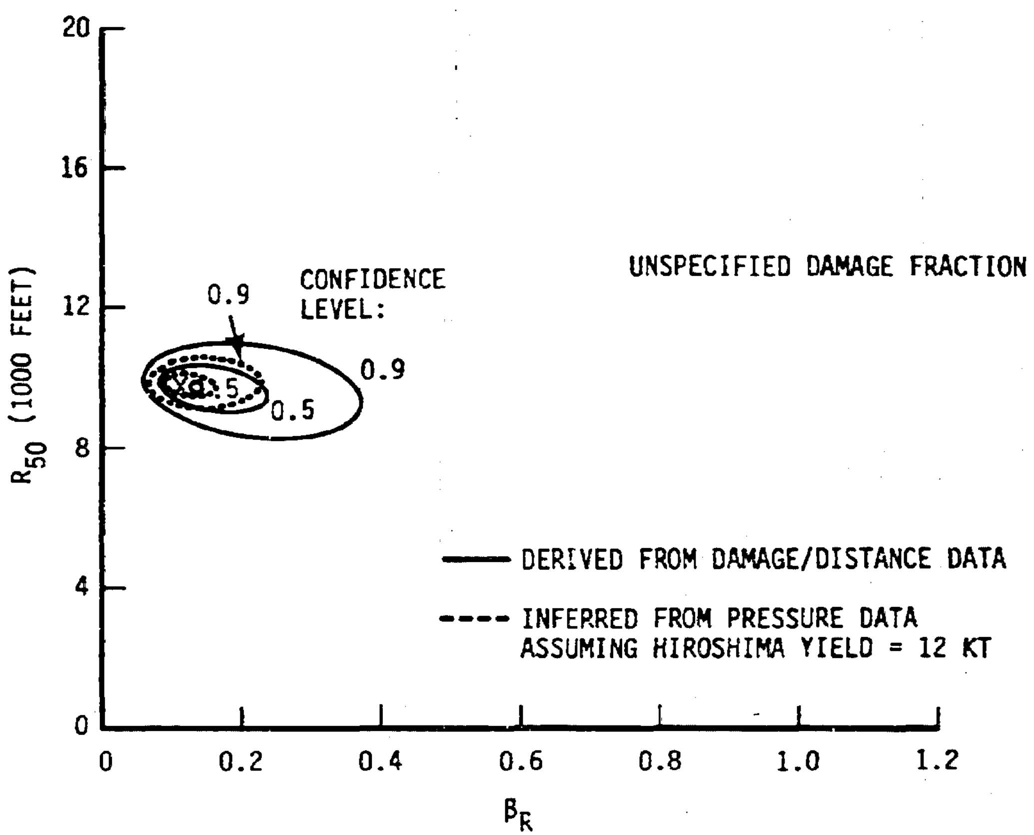


FIGURE 23a

DAMAGE VERSUS DISTANCE DATA

MULTISTORY WOOD FRAME BUILDINGS AT HIROSHIMA

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

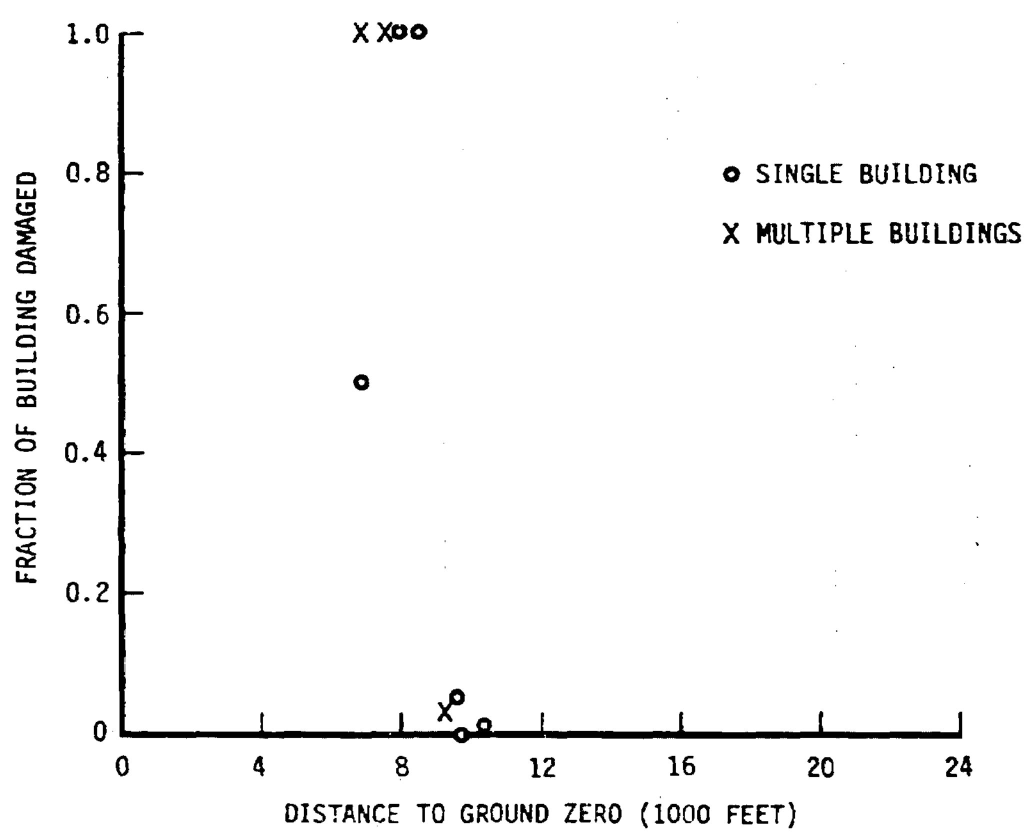


FIGURE 23b

DAMAGE VERSUS DISTANCE DATA

MULTISTORY WOOD FRAME BUILDINGS AT NAGASAKI

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

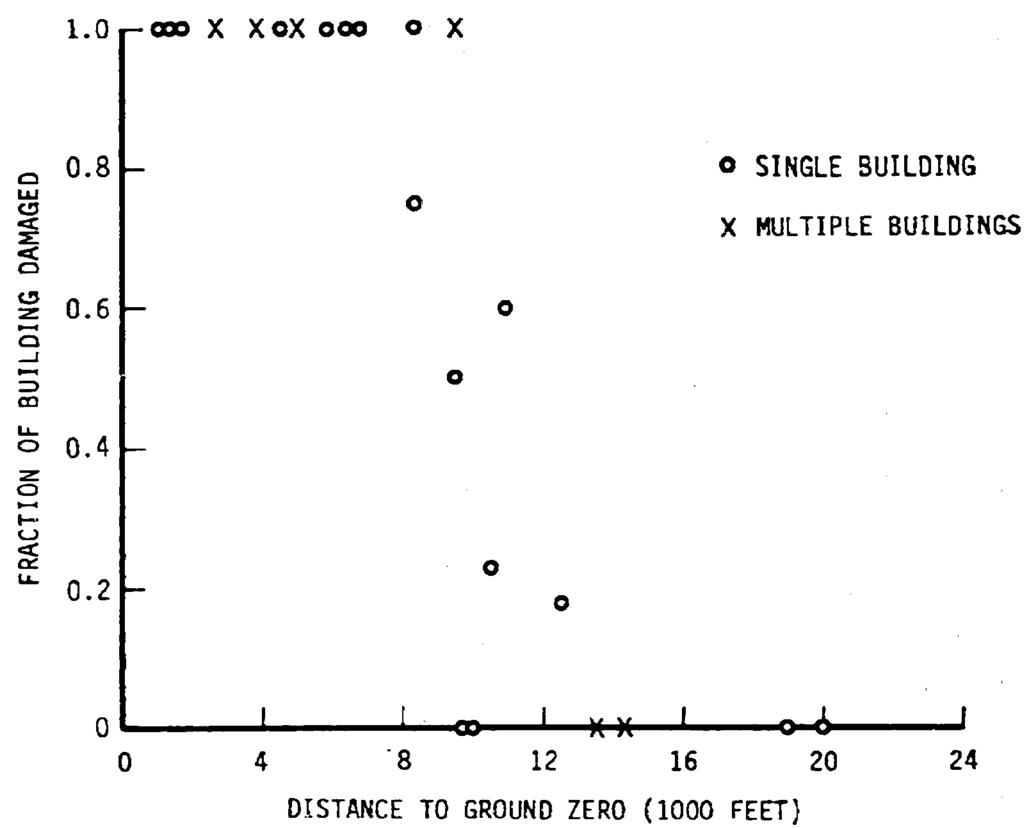


FIGURE 23c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

MULTISTORY WOOD FRAME BUILDINGS AT HIROSHIMA

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

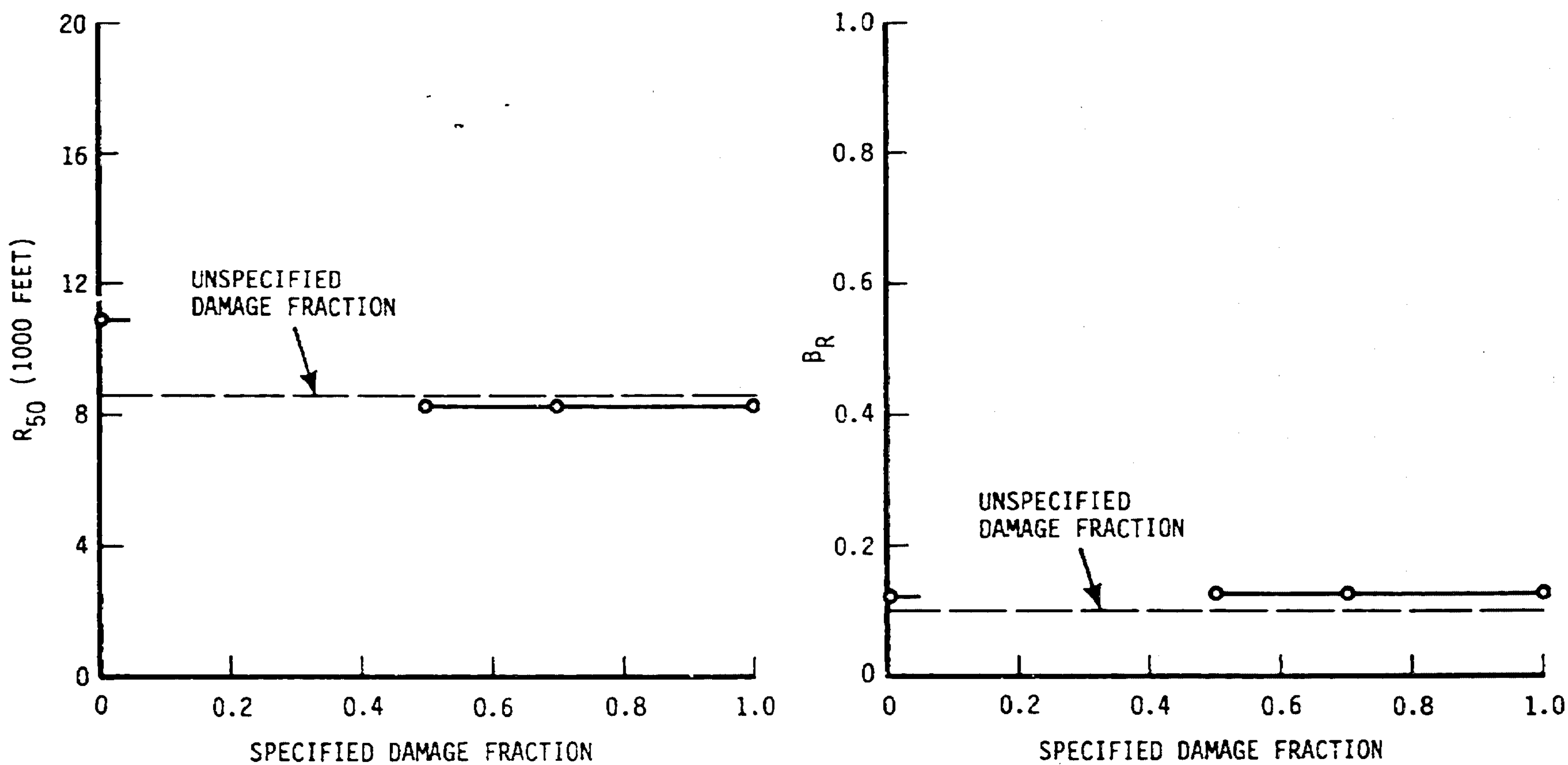


FIGURE 23d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

MULTISTORY WOOD FRAME BUILDINGS AT NAGASAKI

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

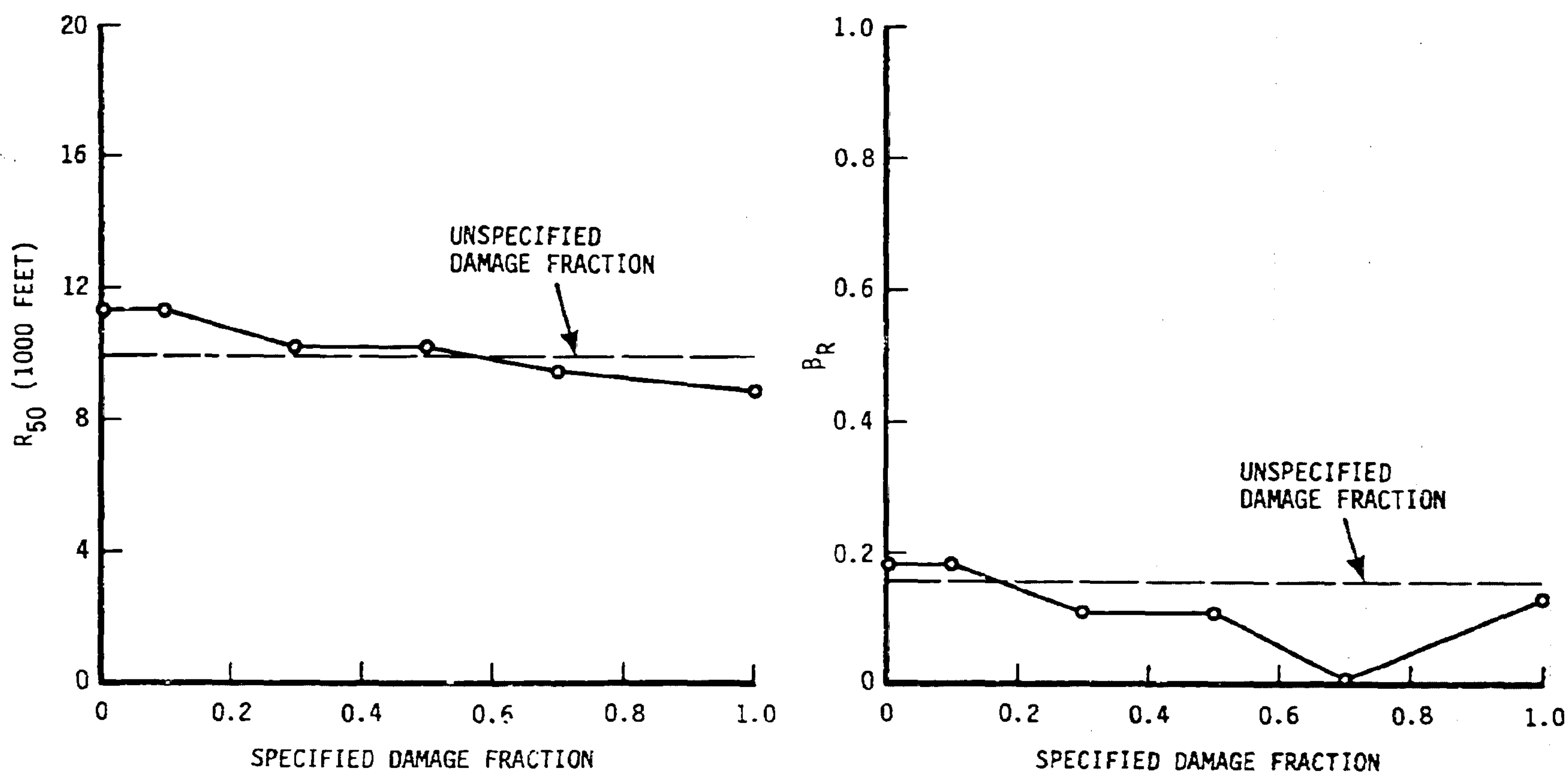


FIGURE 23e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

MULTISTORY WOOD FRAME BUILDINGS

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT

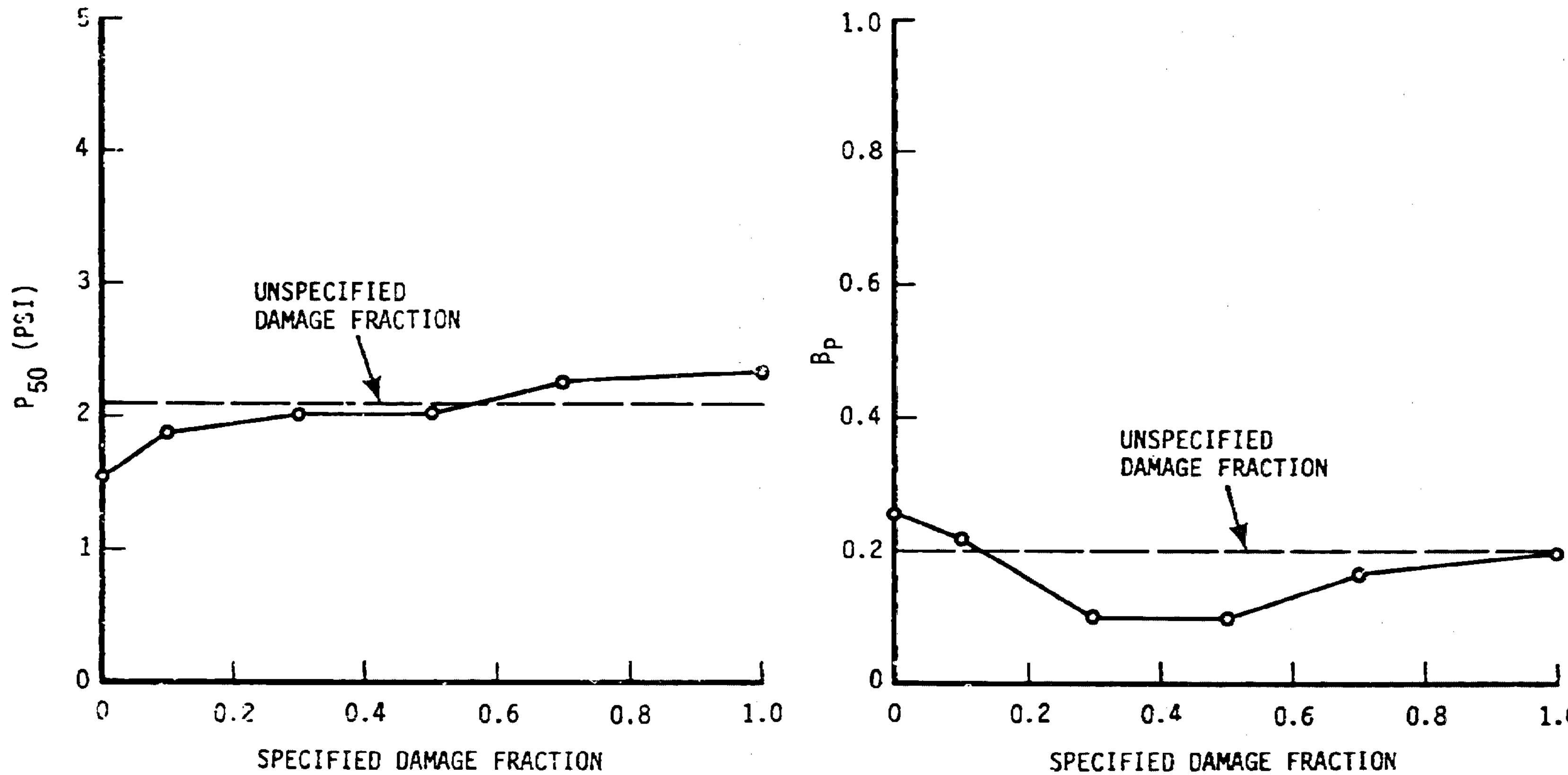


FIGURE 23f

CONFIDENCE REGIONS FOR P_{50} AND β_P

MULTISTORY WOOD FRAME BUILDINGS

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

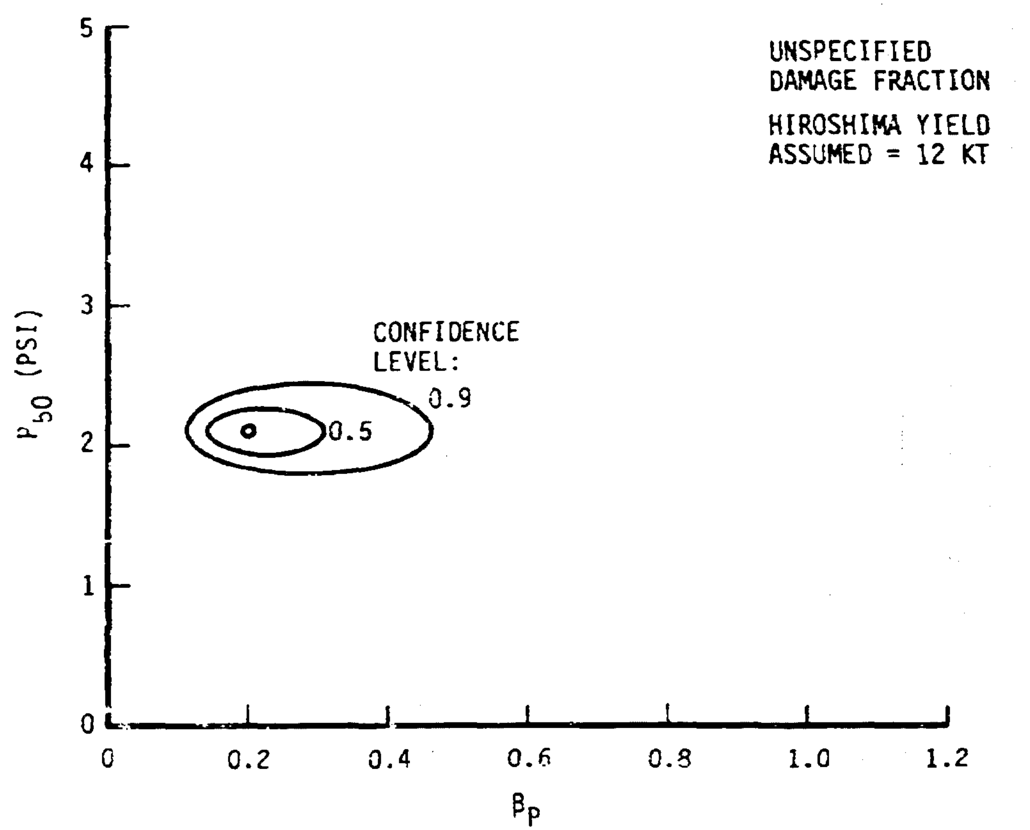


FIGURE 23g

CONFIDENCE REGIONS FOR R_{50} AND β_R

MULTISTORY WOOD FRAME BUILDINGS AT HIROSHIMA

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

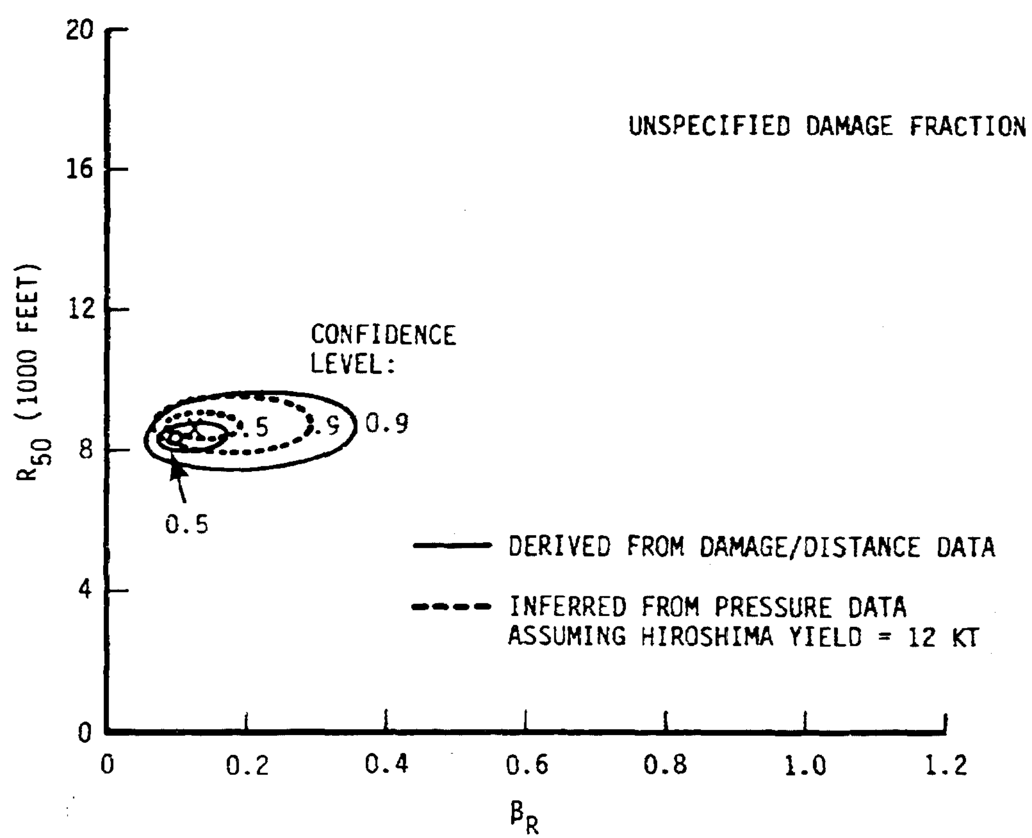


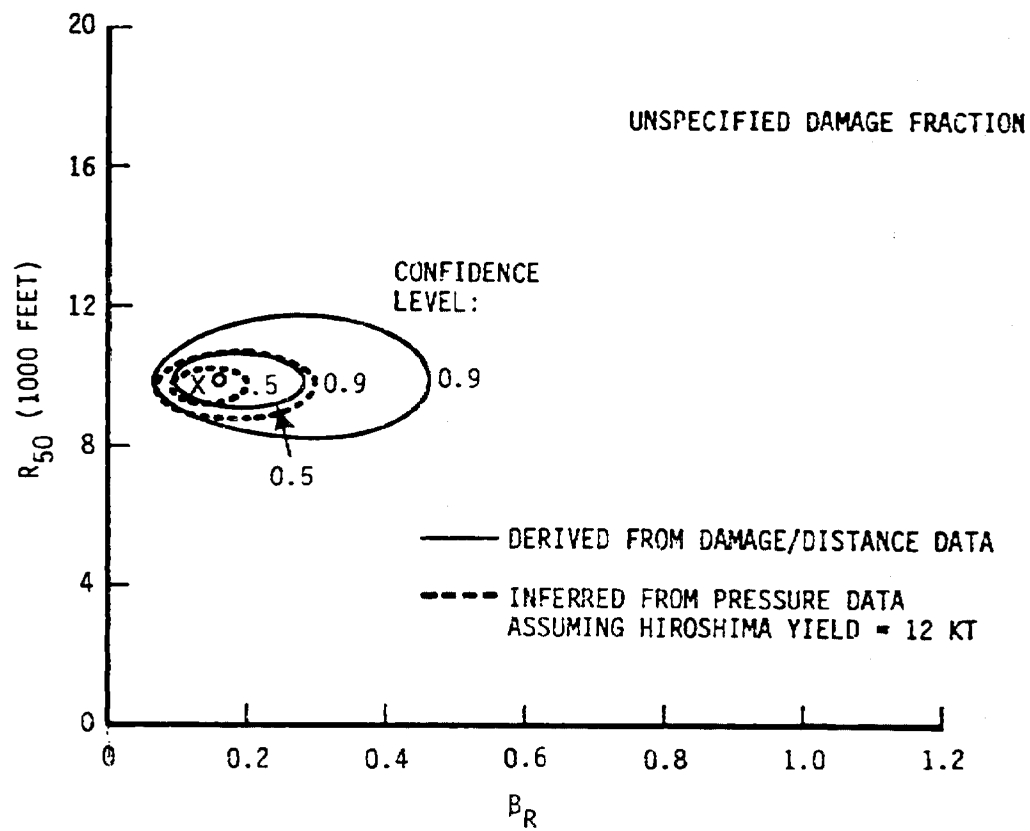
FIGURE 23h

CONFIDENCE REGIONS FOR R_{50} AND β_R

MULTISTORY WOOD FRAME BUILDINGS AT NAGASAKI

WOOD WALLS; WOOD ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA



III. LIGHT STEEL FRAME BUILDINGS

The data base includes 90 Light Steel Frame Buildings, 43 in Hiroshima and 47 in Nagasaki. All are single-story buildings by definition of light steel framing. The breakdown by wall and roof type is as follows:

WALL TYPE	NUMBER OF BUILDINGS Hiroshima	Nagasaki
1	13	35
2	24	6
3	2	0
4	0	6
6	2	0
9	2	0
TOTAL	43	47

ROOF TYPE	NUMBER OF BUILDINGS Hiroshima	Nagasaki
1	0	0
2	19	34
3	20	13
4	0	0
5	2	0
9	2	0
TOTAL	43	47

The vast majority of the buildings (78 out of 90) are of the I-Beam or lattice steel column types (Wall 1 and 2, or normal walls), so that any isolation of the very light column or concrete wall types was impossible. The actual cases examined are shown in the following table with a summary of some of the results.

SUMMARY OF LIGHT STEEL FRAME BUILDINGS

TYPE	M.L.E.		MAX. 90% CONF. LIM.		DATA POINTS			
					TOTAL		±1 SIGMA	
	Q_{50} (P_{50})	β_Q (β_P)	Q_{50} (P_{50})	β_Q (β_P)	H	[illegible]	H	N
SINGLE-STORY								
1. Structural								
a. All	.55	1.14	.36- .96	.76-1.86	43	47	22	17
b. Normal	.53	.94	.36- .96	.50-1.62	37	41	16	11
2. Superficial	(1.90)	(.37)	(1.60-2.25)	(.24- .59)	43	47	11	17
3. Structural Wall								
a. Normal	.56	.82	.38- .94	.52-1.44	37	41	15	15
b. Normal slow wall	.68	1.04	.38-1.76	.58-2.20	13	35	11	9
4. Structural Roof								
a. Steel wall, roof	.64	1.00	.42-1.15	.65-1.70	37	41	18	12
b. Steel wall, slow steel roof	.54	.95	.32-1.00	.60-1.70	19	29	10	7

Two subsets of the Structural Damage criteria were examined, all the Light Steel Frame Buildings and only those with the normal I-Beam or lattice steel columns (no concrete or very light columns). Note that the mean dynamic pressure is very nearly the same for each set, but the β_Q drops when the abnormal wall types are excluded. This is equivalent to a σ_d drop from 39 to 32.5. The placement of the data points prevented any significant results from being obtained by further breakdowns.

The Superficial Damage criteria was examined for all the buildings only, since the type of columns makes no difference to wall and roof stripping. The σ_d for the Superficial Damage was about 23.

For the Structural Damage to wall criteria, only the normal type walls and a subset with slow-failing wall covers were examined. It was felt that including the concrete reinforced frame (or the very light column) types would not give a meaningful class, since type would probably be much more resistant to structural wall damage (the very light columns would have the opposite effect). The normal wall set has a mean pressure about the same as for the Structural Damage criteria, but the β_Q is significantly reduced. This is equivalent to a σ_d of 28 consistent with the other major classes of buildings (e.g., Wood Frame). The slow-failing wall subset gives a higher mean pressure but because of a higher β_Q and much larger confidence intervals, the result is not significant. Note also that the buildings with normal walls and quick wall types number 6 in Nagasaki and 24 in Hiroshima. The result of adding the six buildings at Nagasaki is not important, but in Hiroshima the effect is great. The slow wall subset does not have any buildings at a distance further than about 8000 feet from the ground zero at Hiroshima, and the quick wall buildings are mostly at greater than 8000 feet, so that the combined is a much better data set.

Thus, taking only the reliable data sets, the MLE σ_d's vary only from about 28 to 34, except for the Superficial Damage. A possible reason for this is detailed in the main text. A larger data set for Superficial Damage is examined later when Light and Heavy Steel Frame Buildings are combined.

FIGURE 24a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA
STRUCTURAL DAMAGE CRITERIA

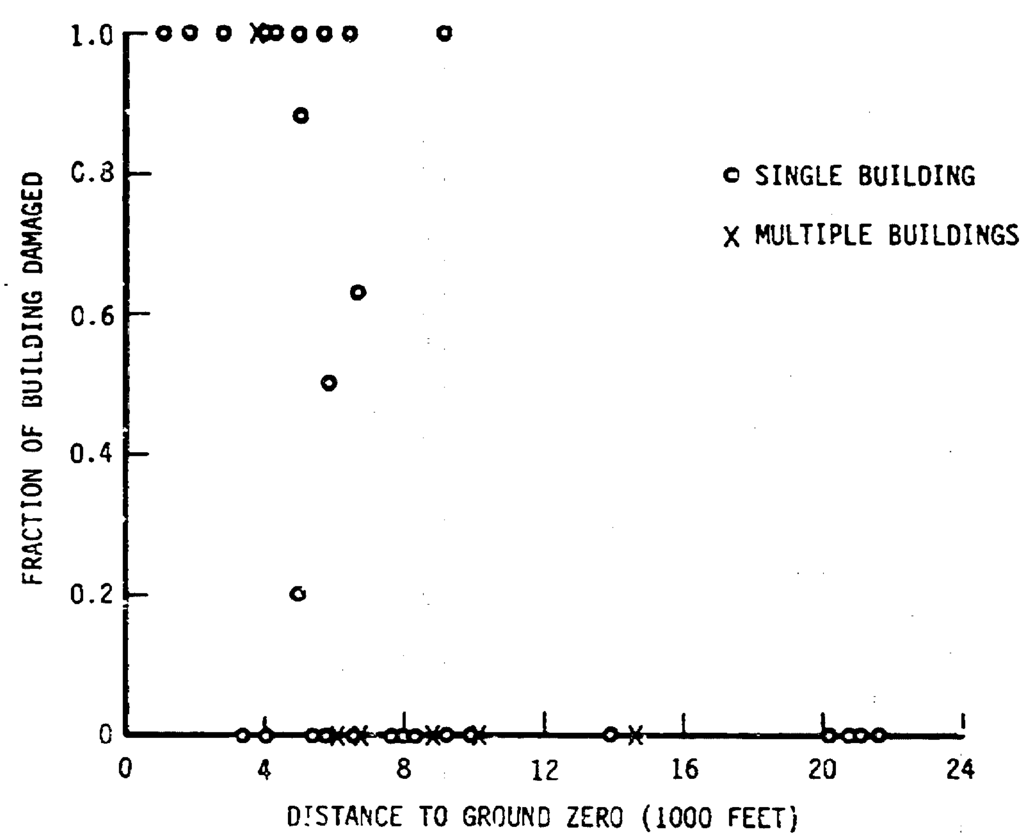


FIGURE 24b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE CRITERIA

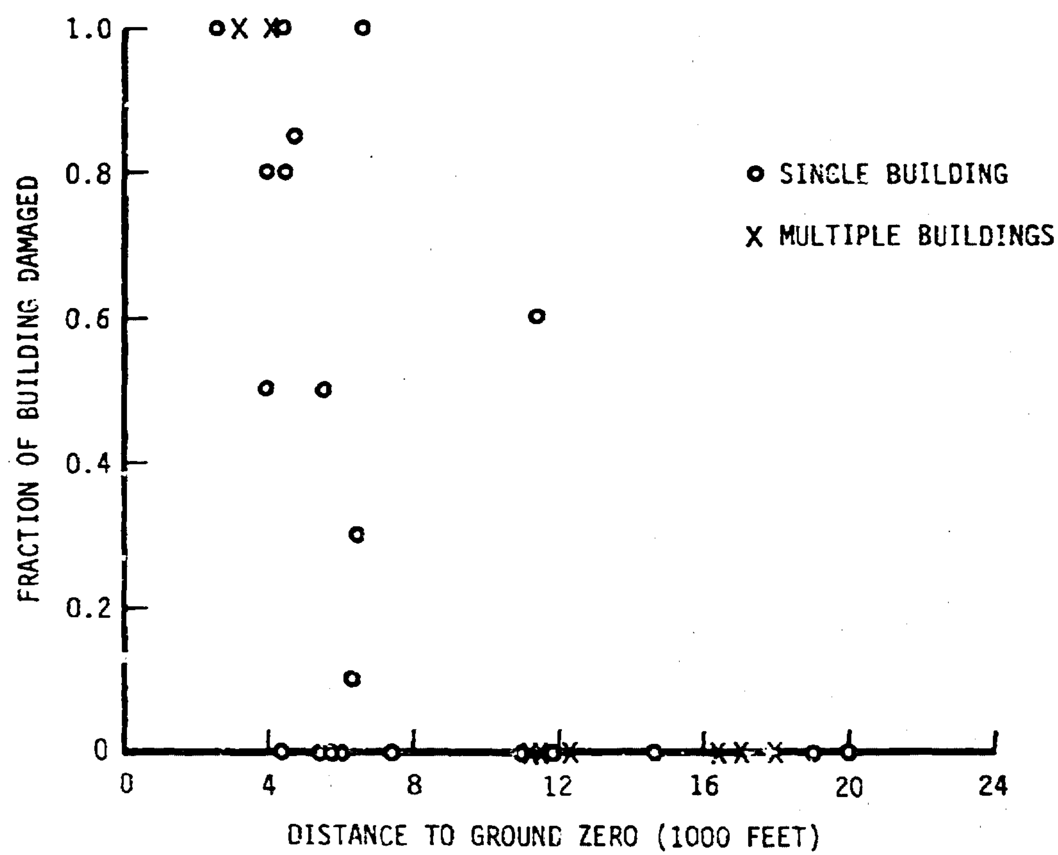


FIGURE 24c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA

STRUCTURAL DAMAGE CRITERIA

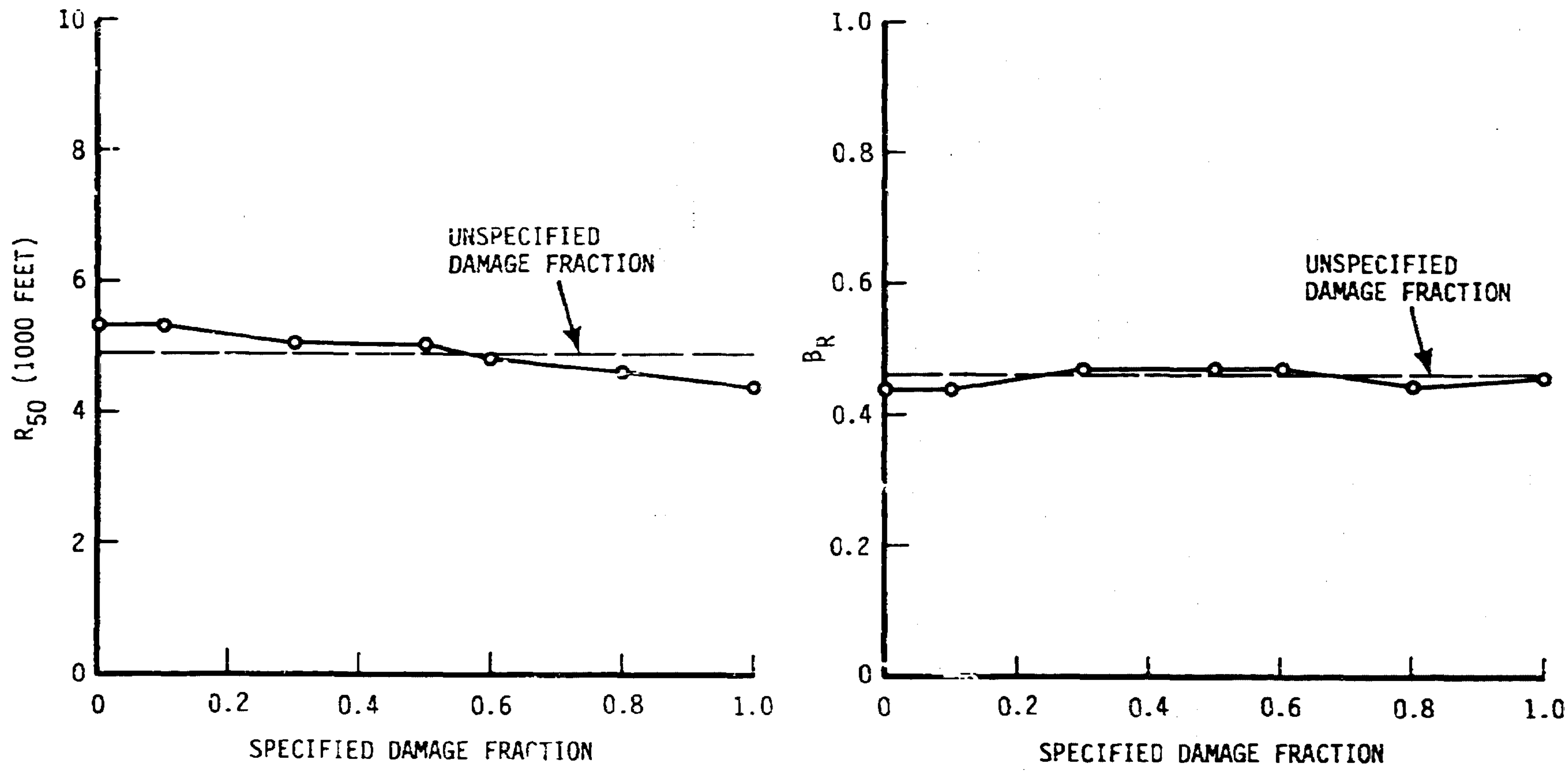


FIGURE 24d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE CRITERIA

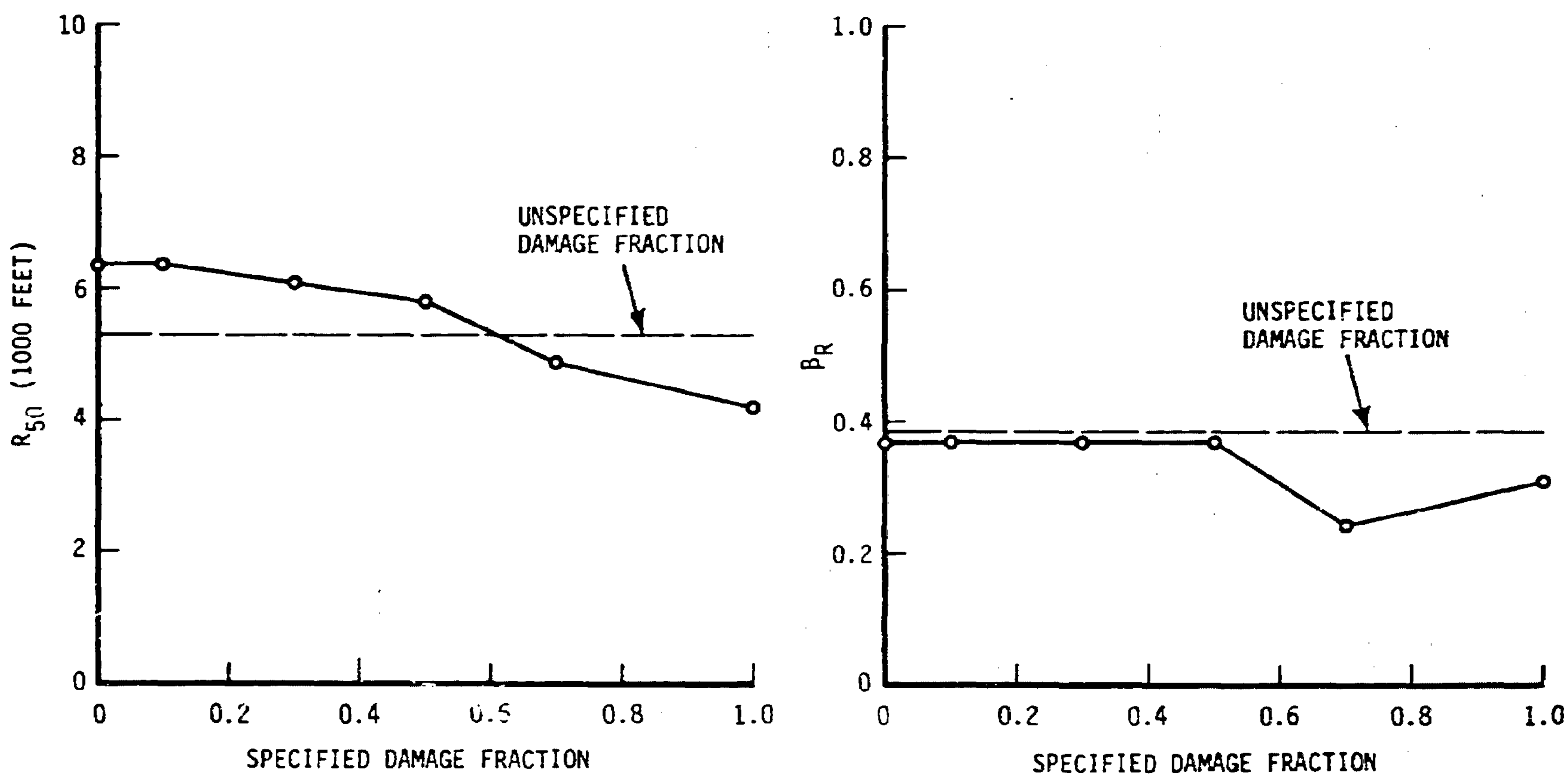


FIGURE 24e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF Q_{50} AND β_Q

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS
STRUCTURAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT

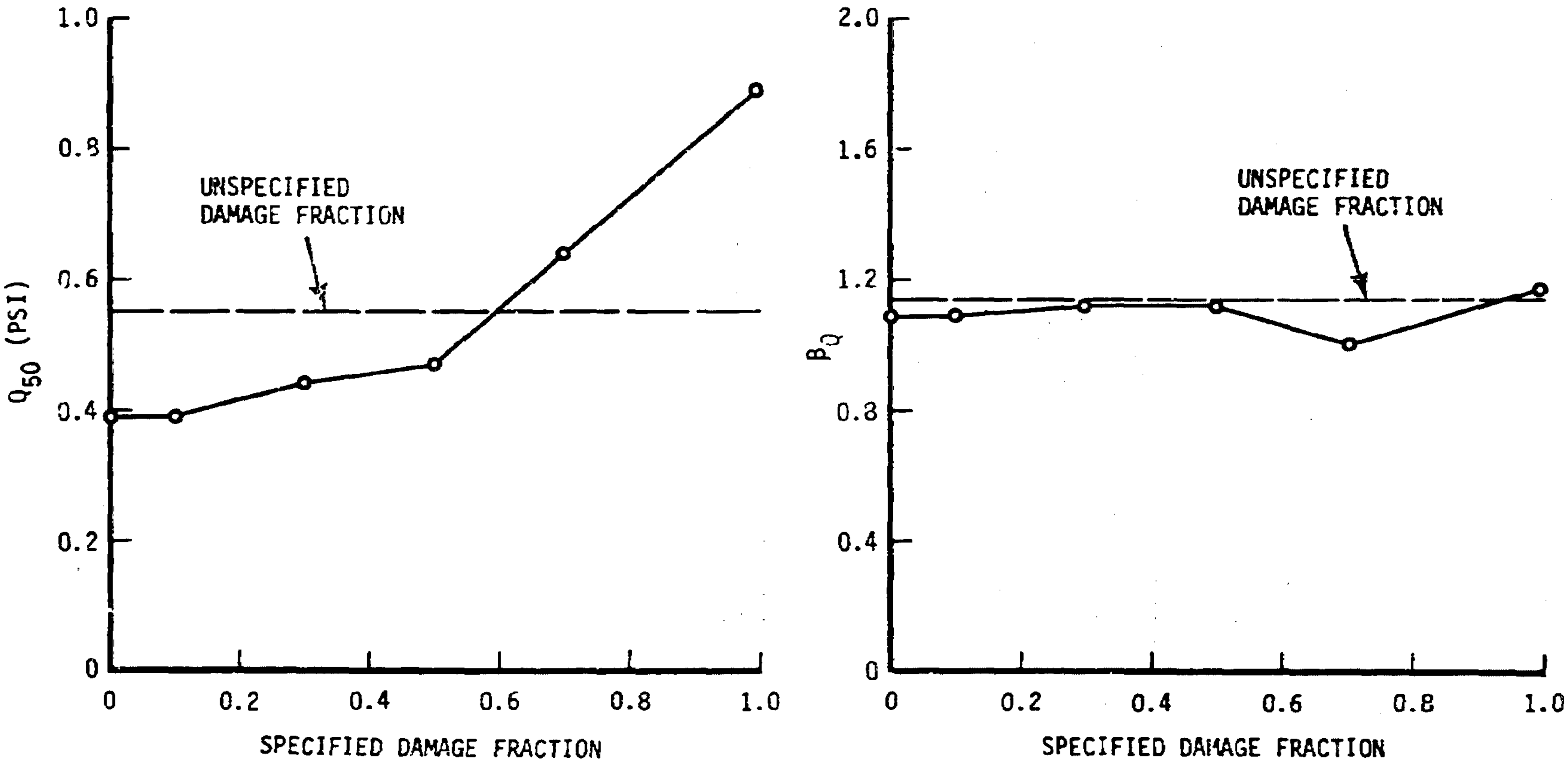


FIGURE 24f

CONFIDENCE REGIONS FOR Q_{50} AND β_Q

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS

STRUCTURAL DAMAGE CRITERIA

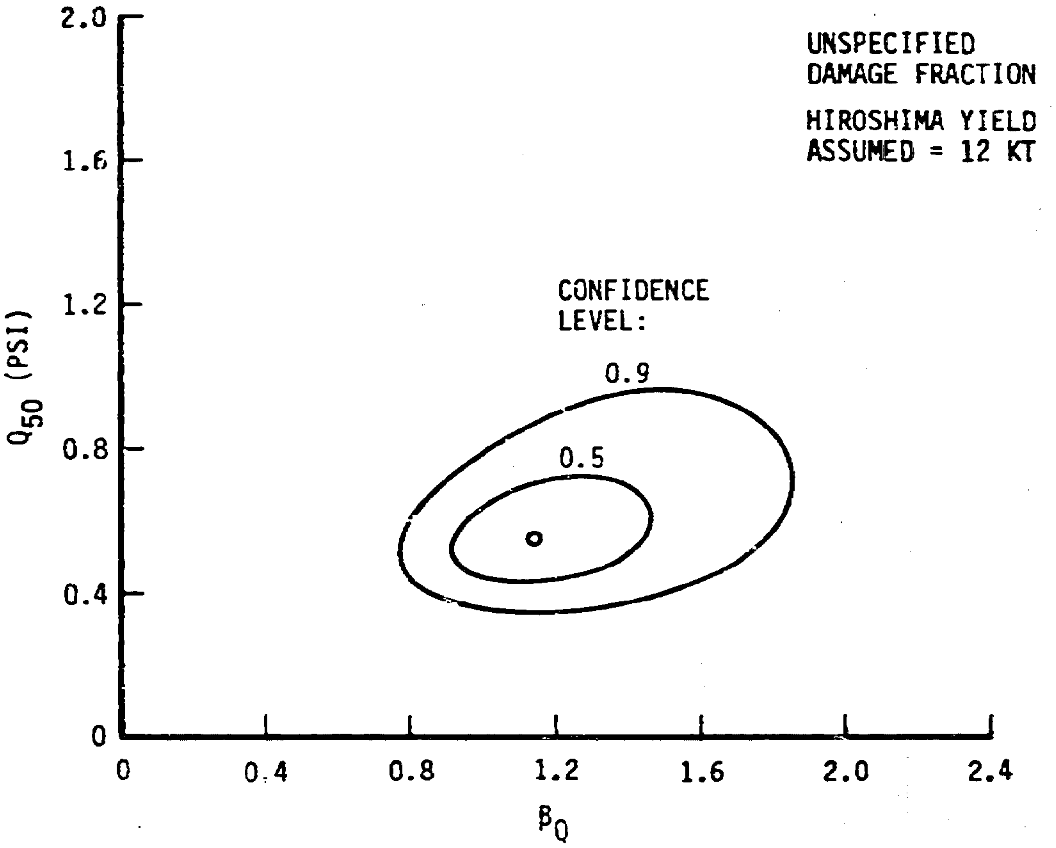


FIGURE 24g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA

STRUCTURAL DAMAGE CRITERIA

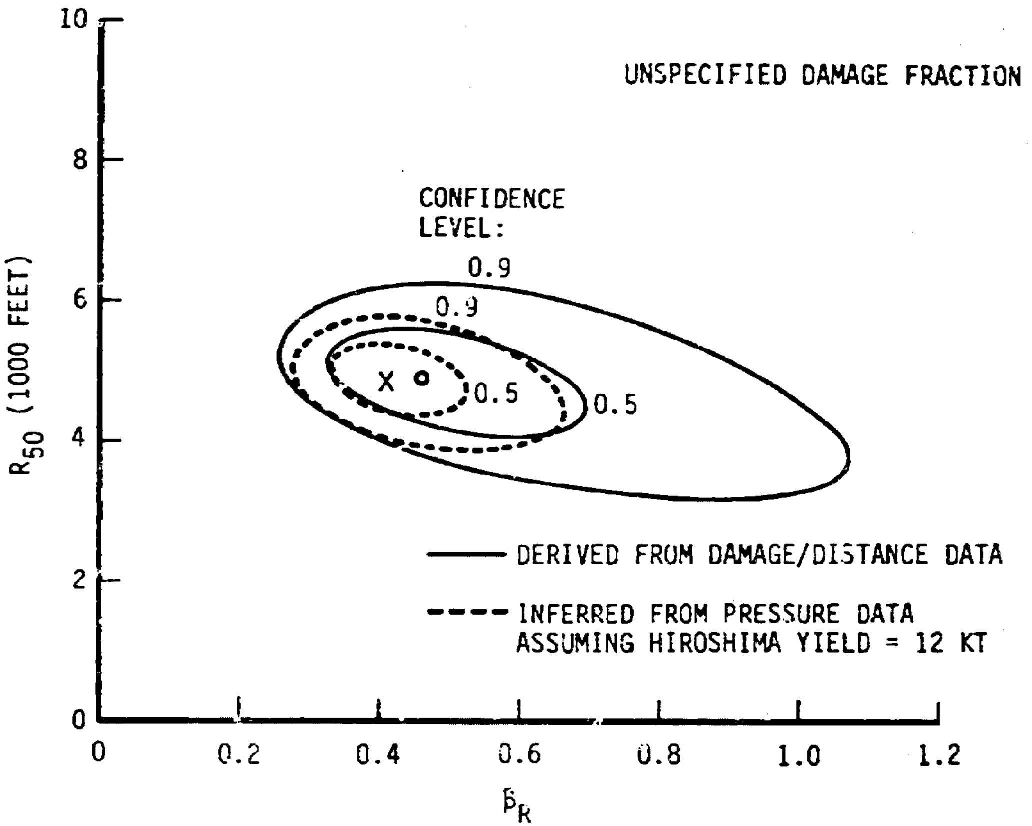


FIGURE 24h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE CRITERIA

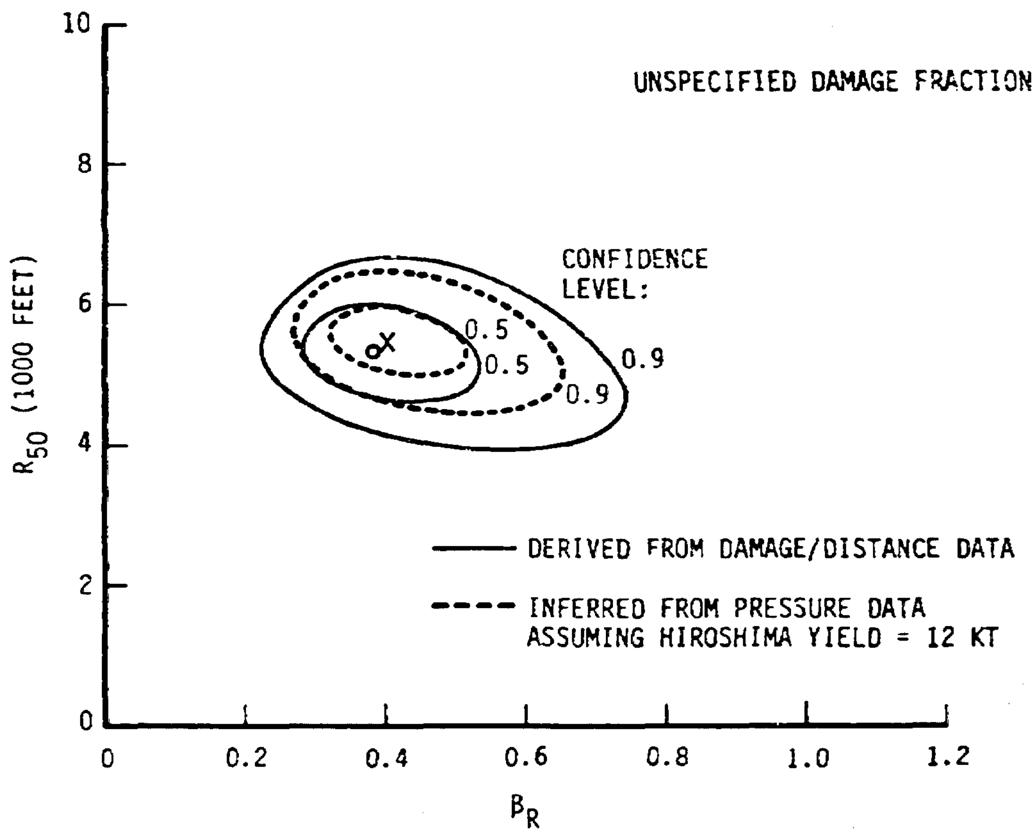


FIGURE 25a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA
I-BEAM OR LATTICE STEEL COLUMNS; STEEL ROOF TRUSSES
STRUCTURAL DAMAGE CRITERIA

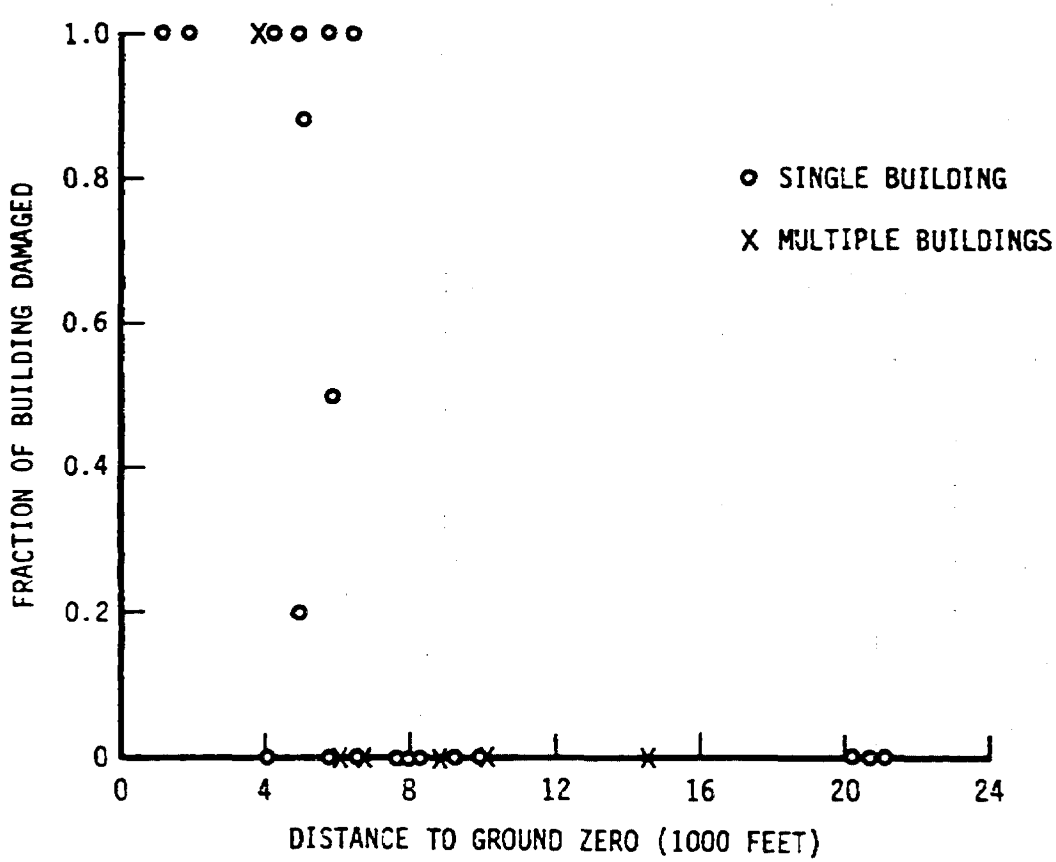


FIGURE 25b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI
I-BEAM OR LATTICE STEEL COLUMNS; STEEL ROOF TRUSSES
STRUCTURAL DAMAGE CRITERIA

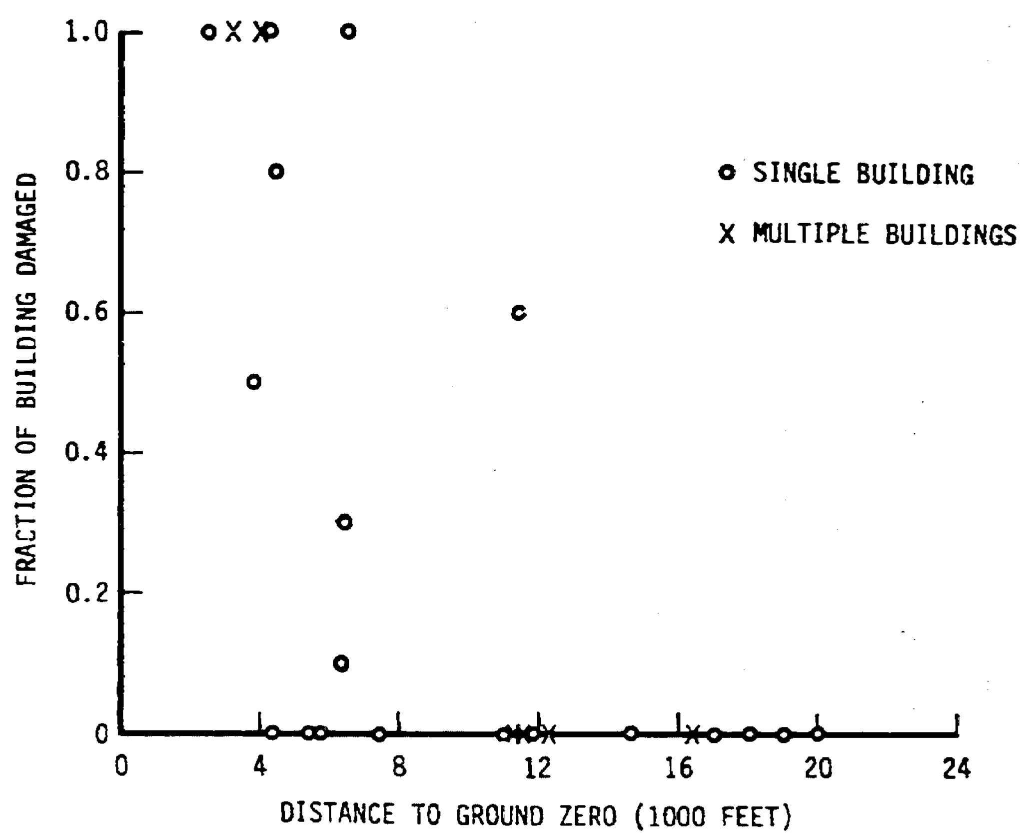


FIGURE 25c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA

I-BEAM OR LATTICE STEEL COLUMNS; STEEL ROOF TRUSSES

STRUCTURAL DAMAGE CRITERIA

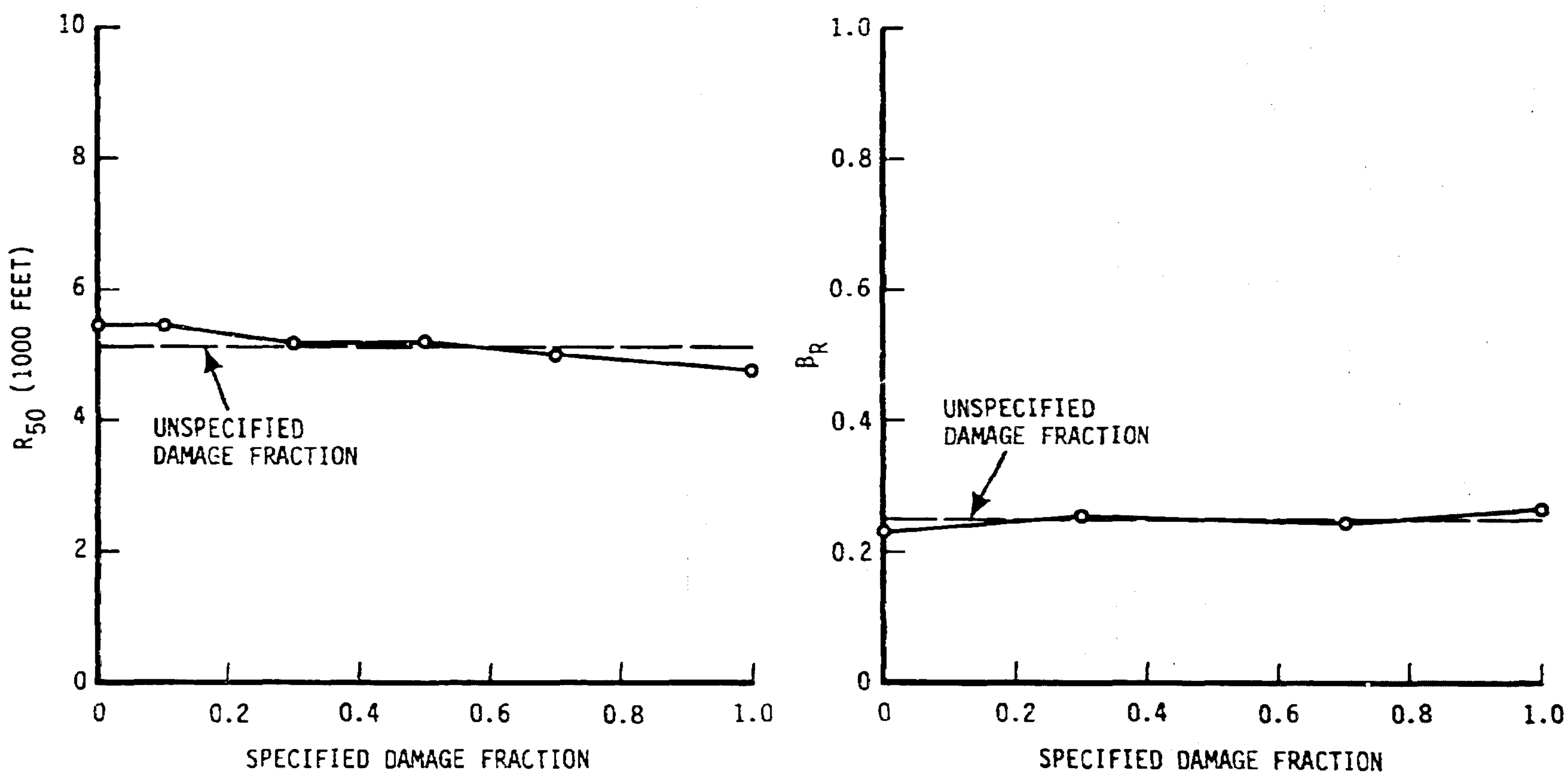


FIGURE 25d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI

I-BEAM OR LATTICE STEEL COLUMNS; STEEL ROOF TRUSSES

STRUCTURAL DAMAGE CRITERIA

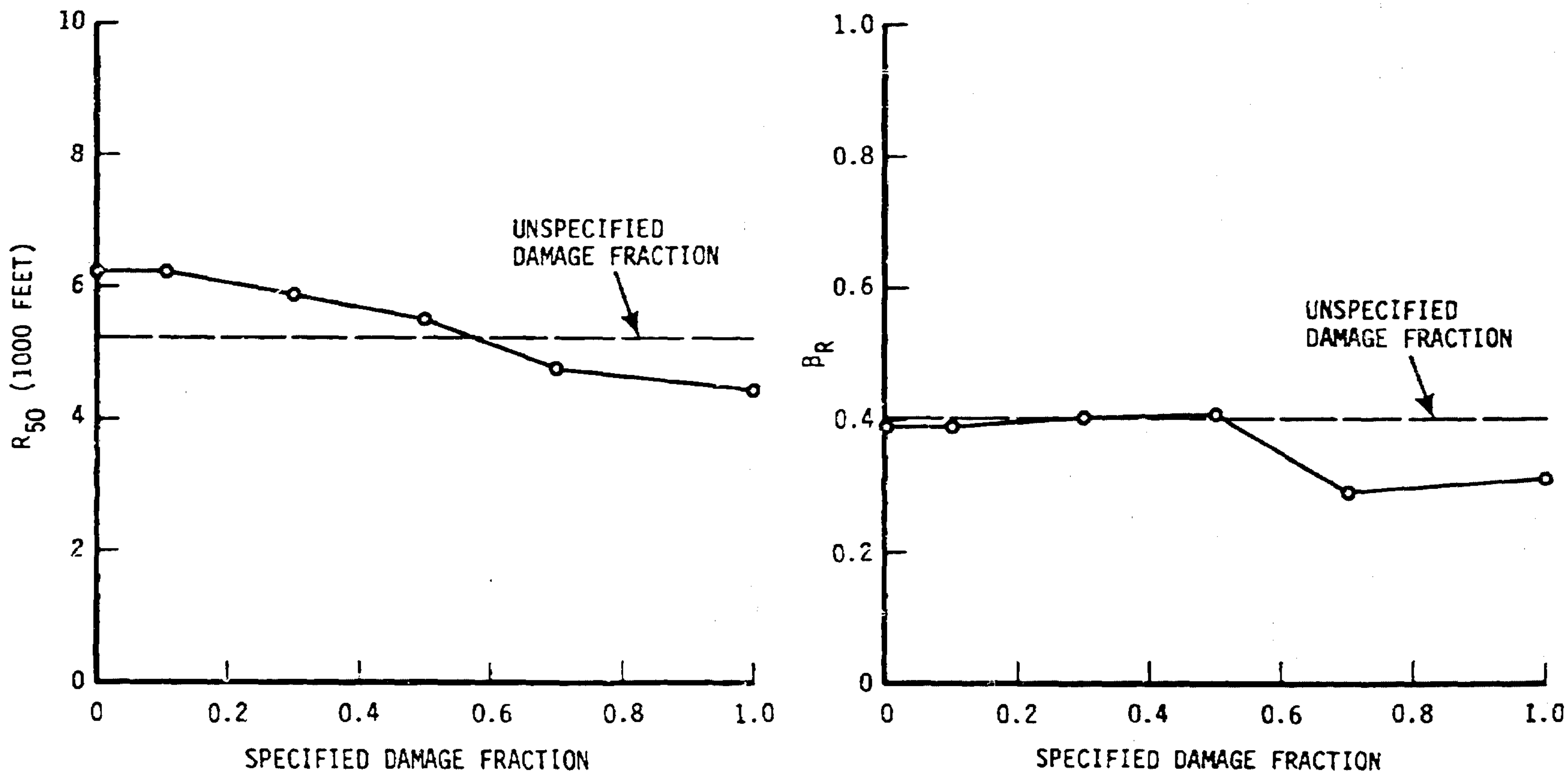


FIGURE 25e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF Q_{50} AND β_Q

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS

I-BEAM OR LATTICE STEEL COLUMNS; STEEL ROOF TRUSSES

STRUCTURAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT

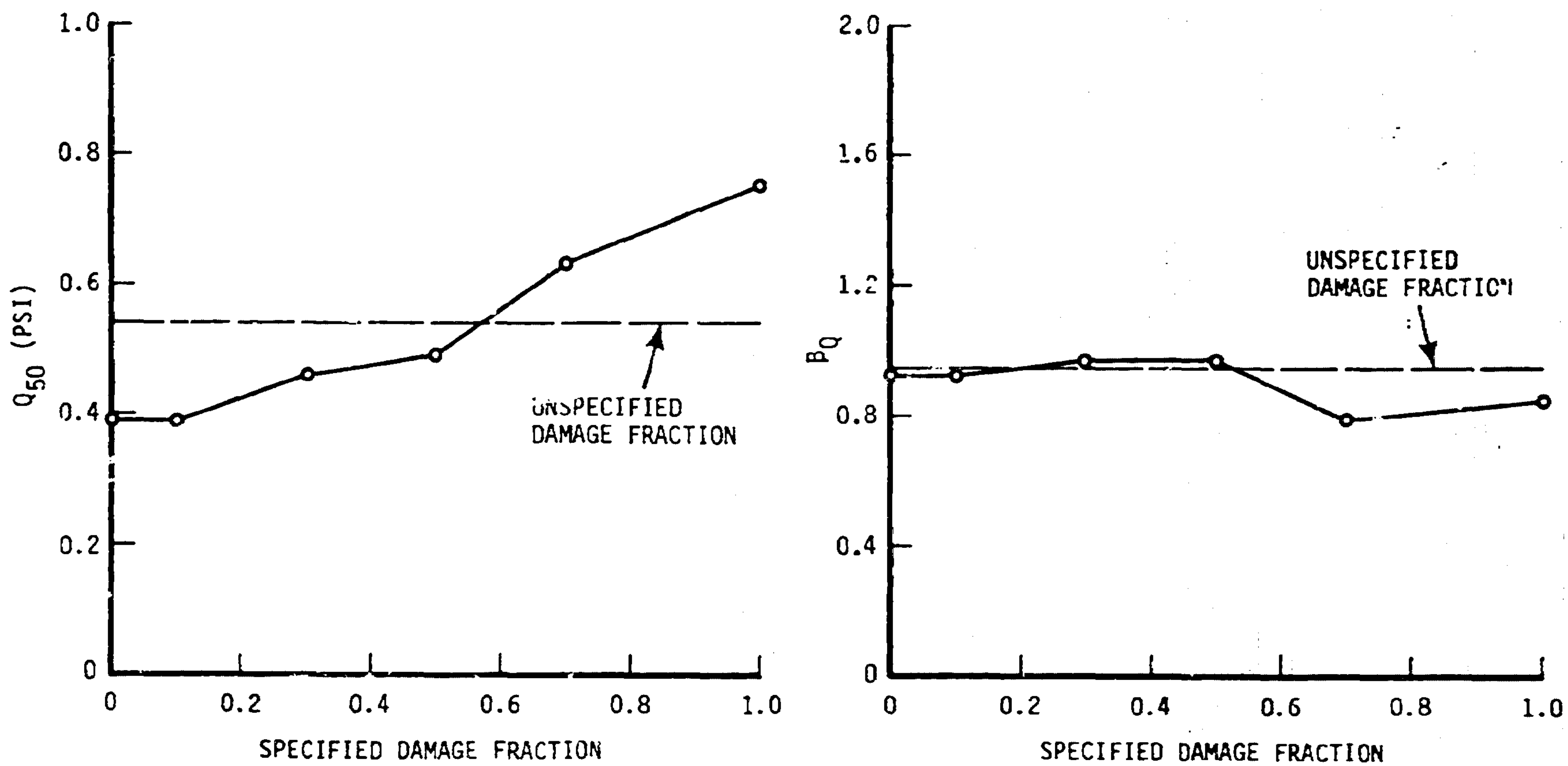


FIGURE 25f

CONFIDENCE REGIONS FOR Q_{50} AND β_Q

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS

I-BEAM OR LATTICE STEEL COLUMNS; STEEL ROOF TRUSSES

STRUCTURAL DAMAGE CRITERIA

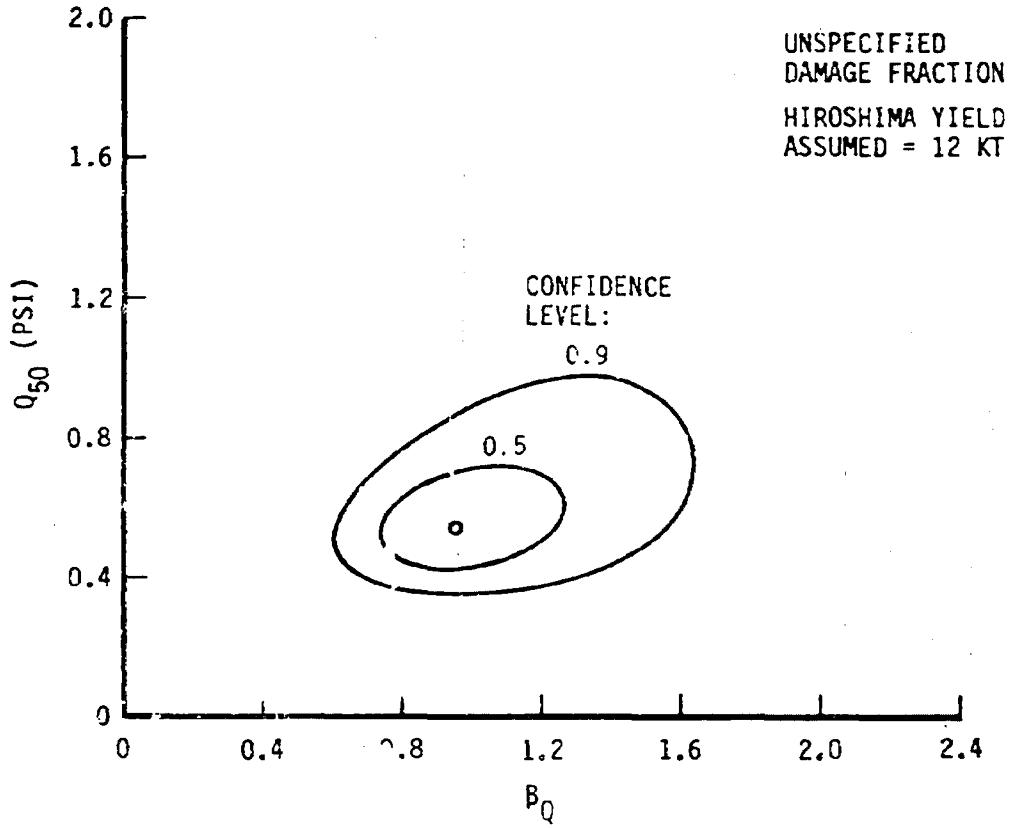


FIGURE 25g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA
I-BEAM OR LATTICE STEEL COLUMNS; STEEL ROOF TRUSSES
STRUCTURAL DAMAGE CRITERIA

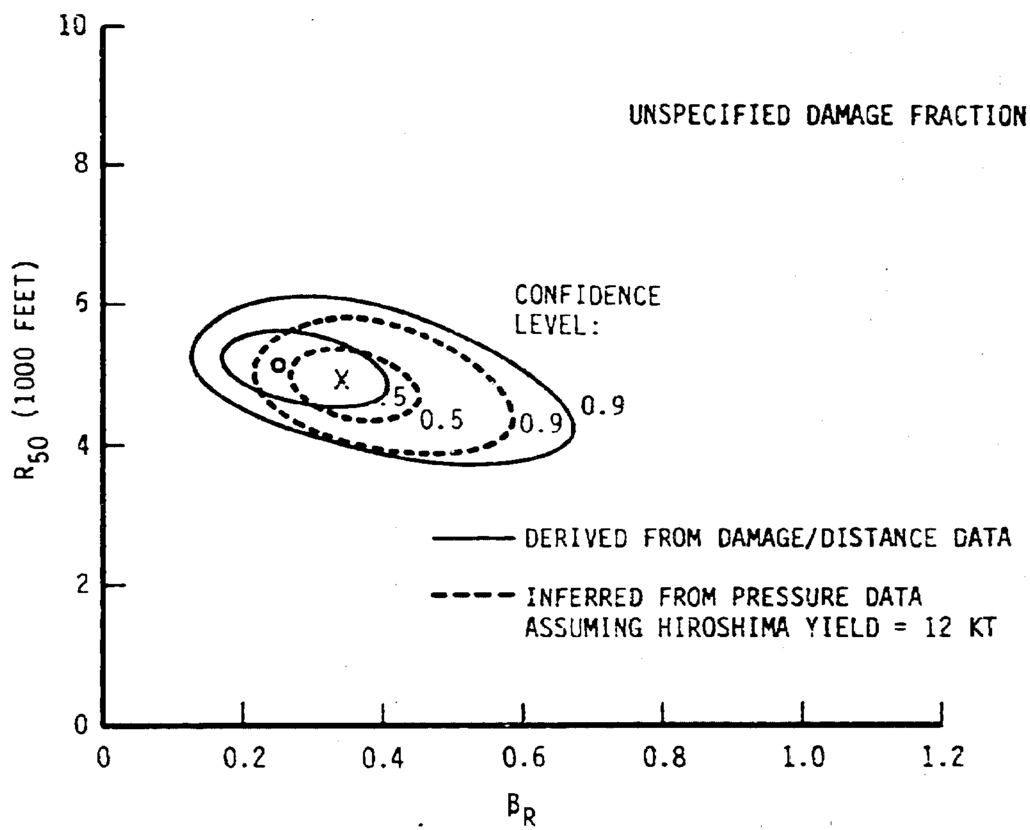


FIGURE 25h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI
I-BEAM OR LATTICE STEEL COLUMNS; STEEL ROOF TRUSSES
STRUCTURAL DAMAGE CRITERIA

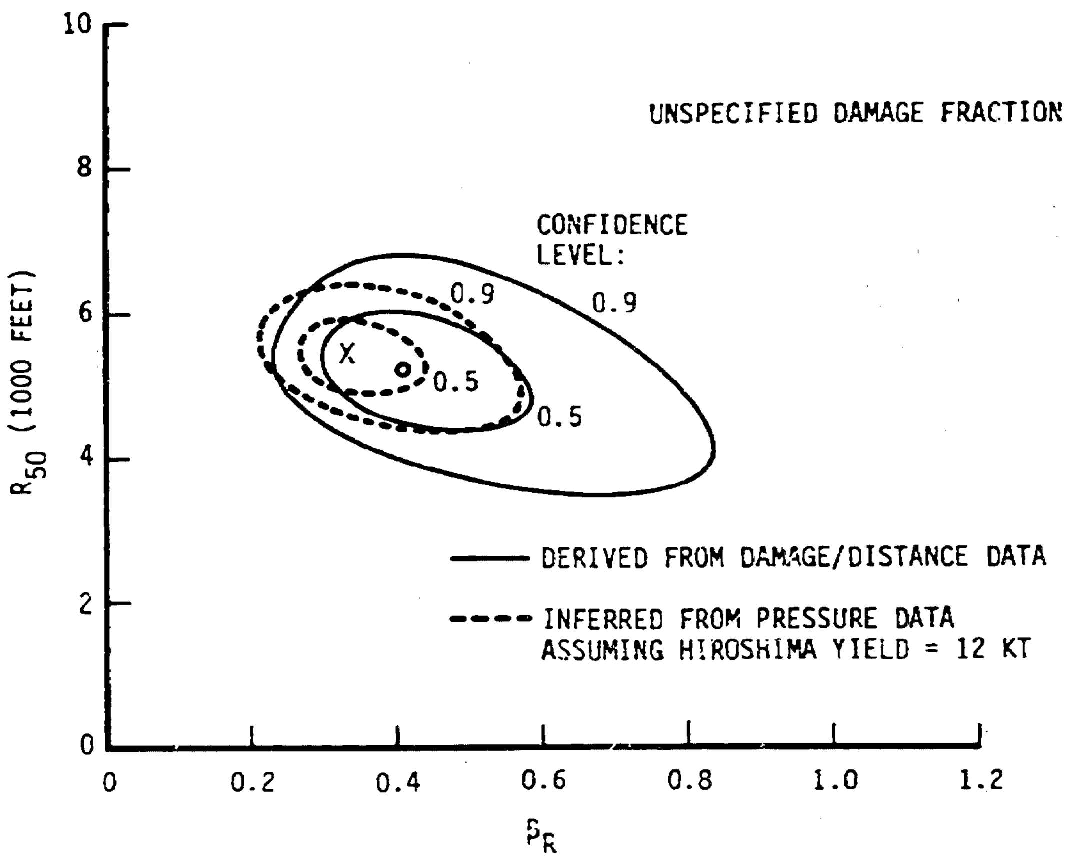


FIGURE 26a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA
SUPERFICIAL DAMAGE CRITERIA

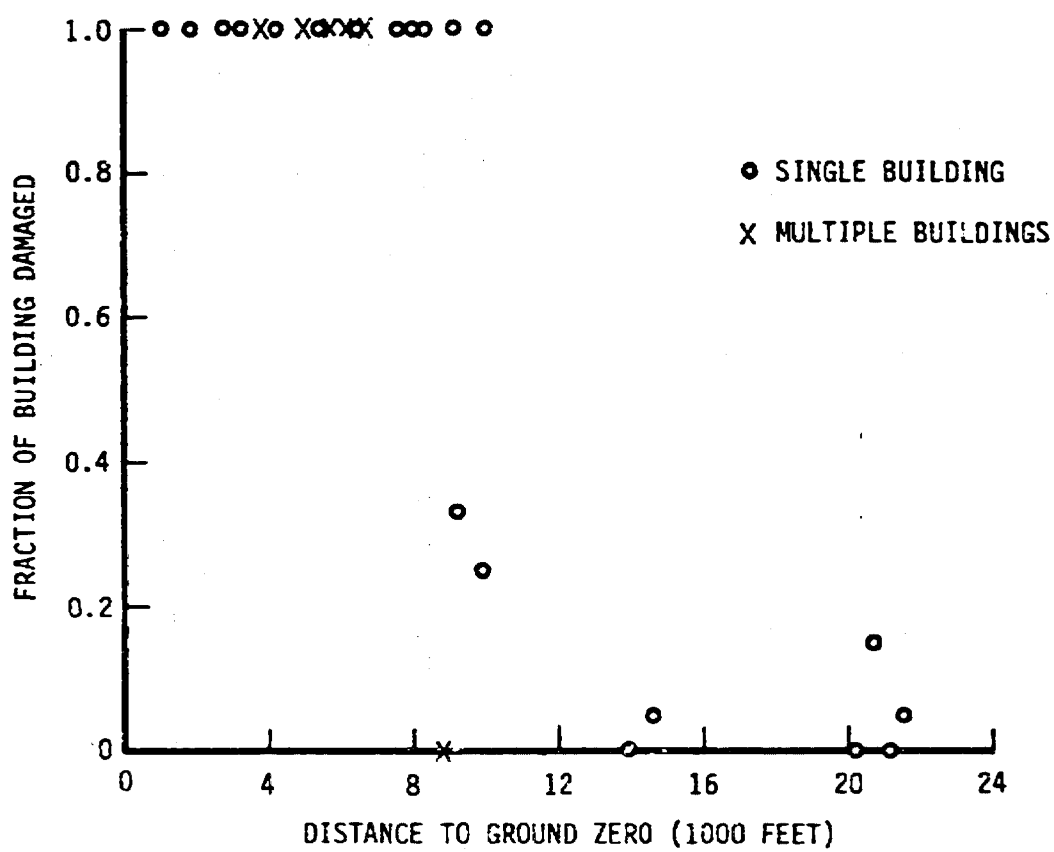


FIGURE 26b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI
SUPERFICIAL DAMAGE CRITERIA

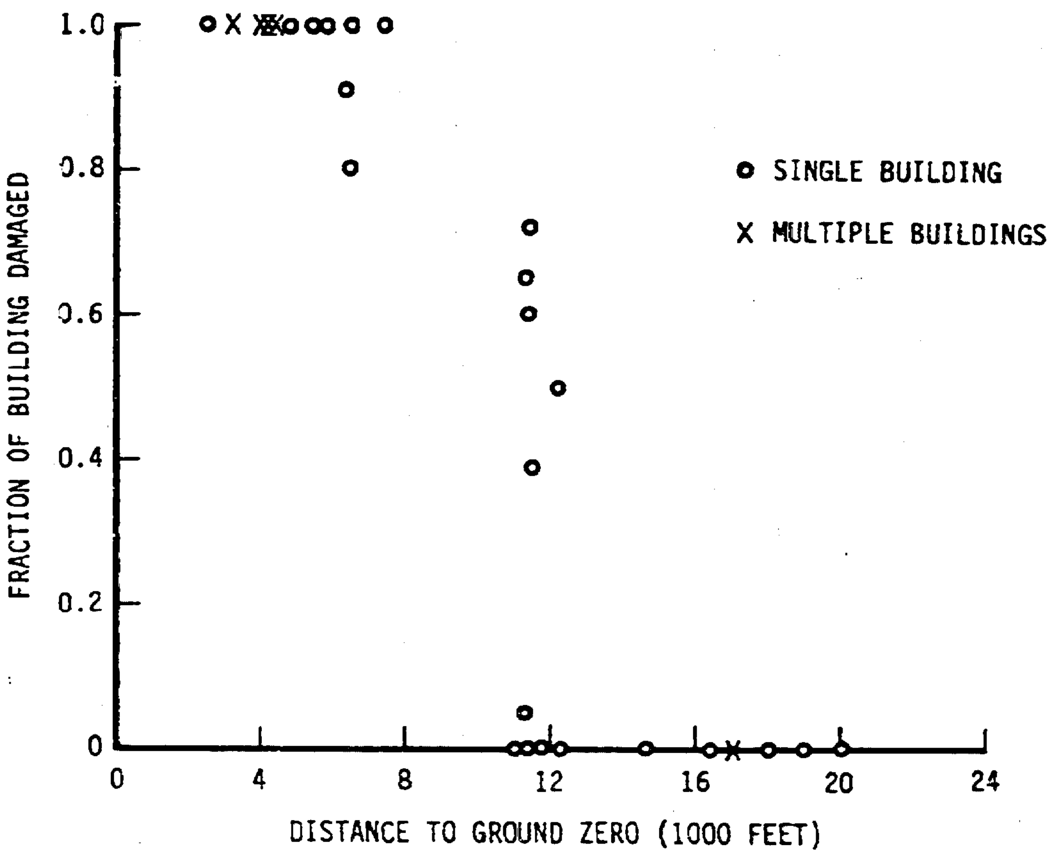
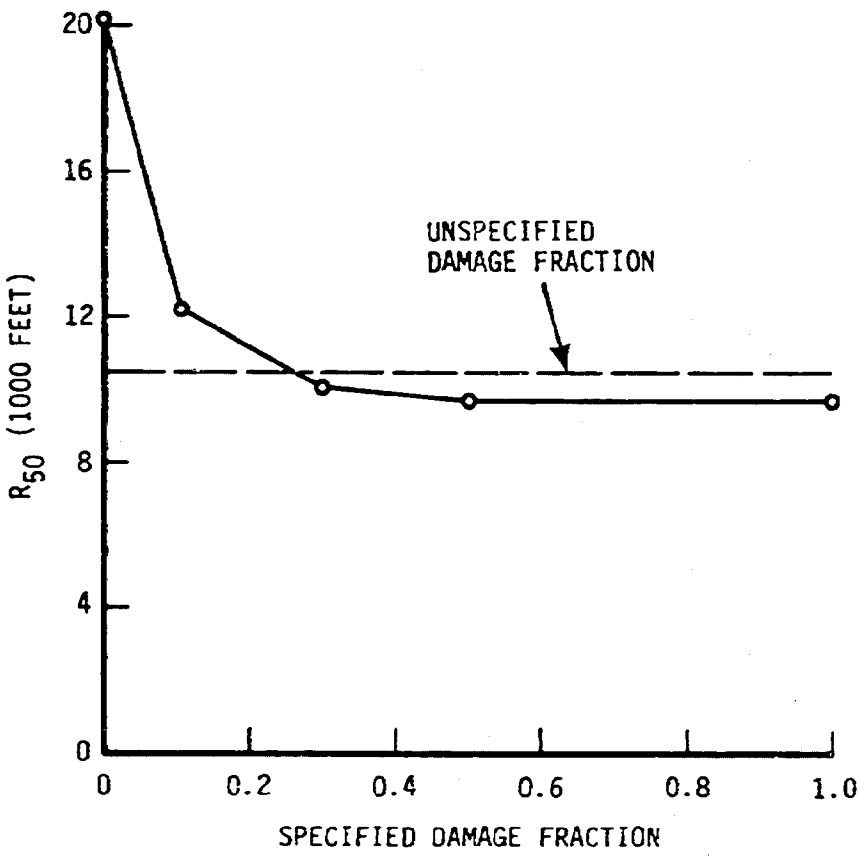


FIGURE 26c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA
SUPERFICIAL DAMAGE CRITERIA



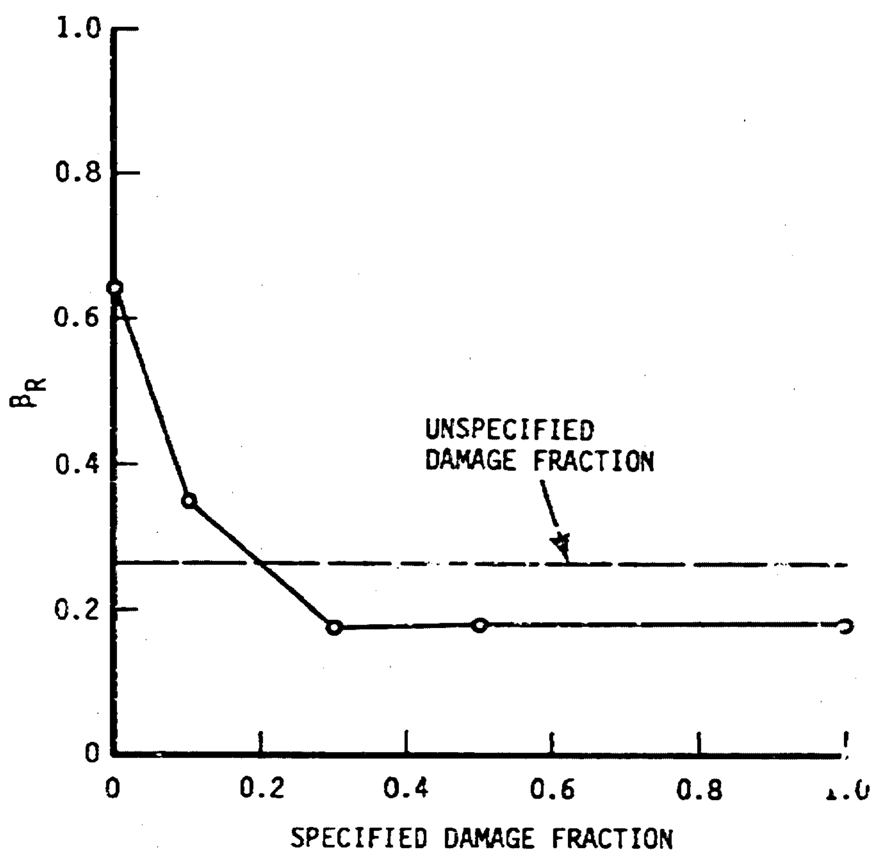


FIGURE 26d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI

SUPERFICIAL DAMAGE CRITERIA

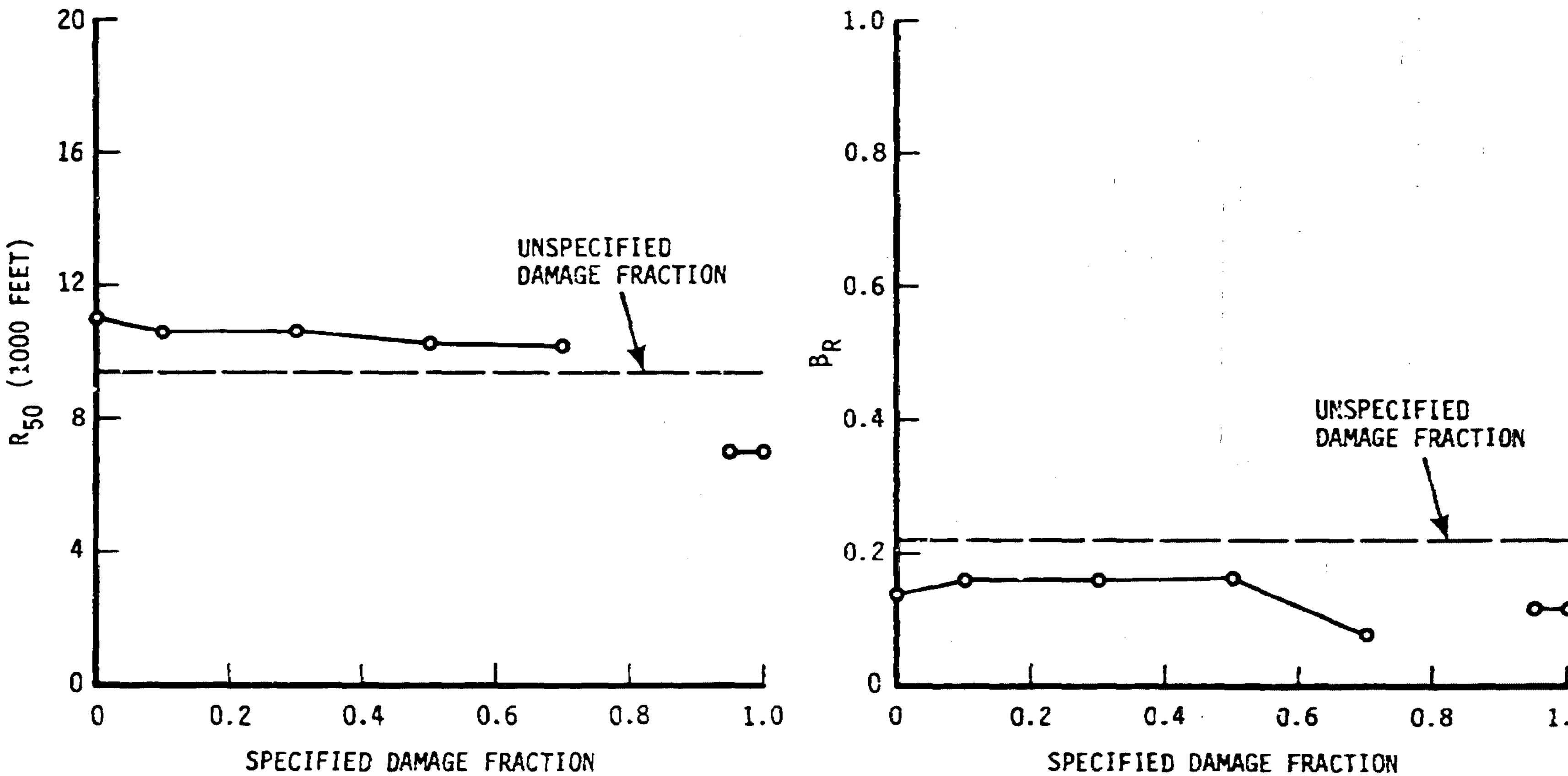


FIGURE 26e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF Q_{50} AND β_Q

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS
SUPERFICIAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT

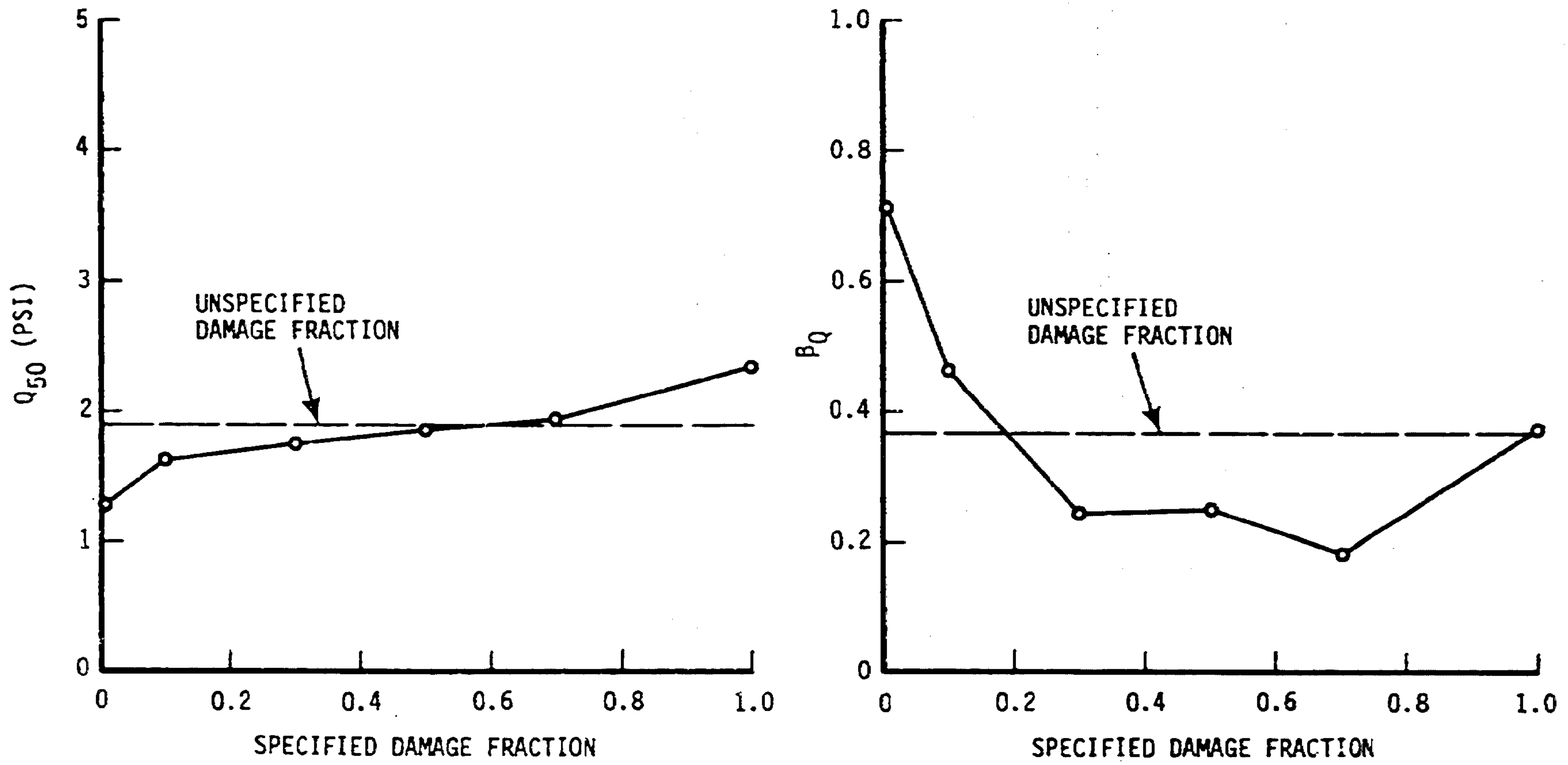


FIGURE 26f

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS
SUPERFICIAL DAMAGE CRITERIA

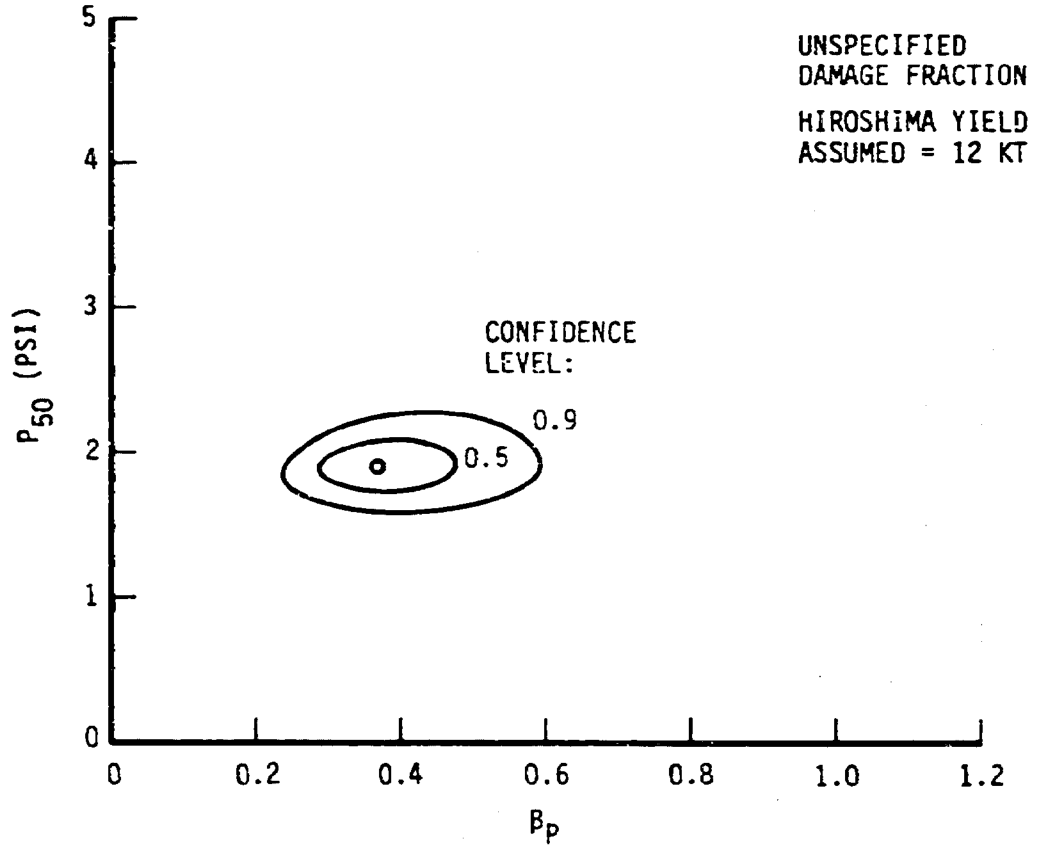


FIGURE 26g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA

SUPERFICIAL DAMAGE CRITERIA

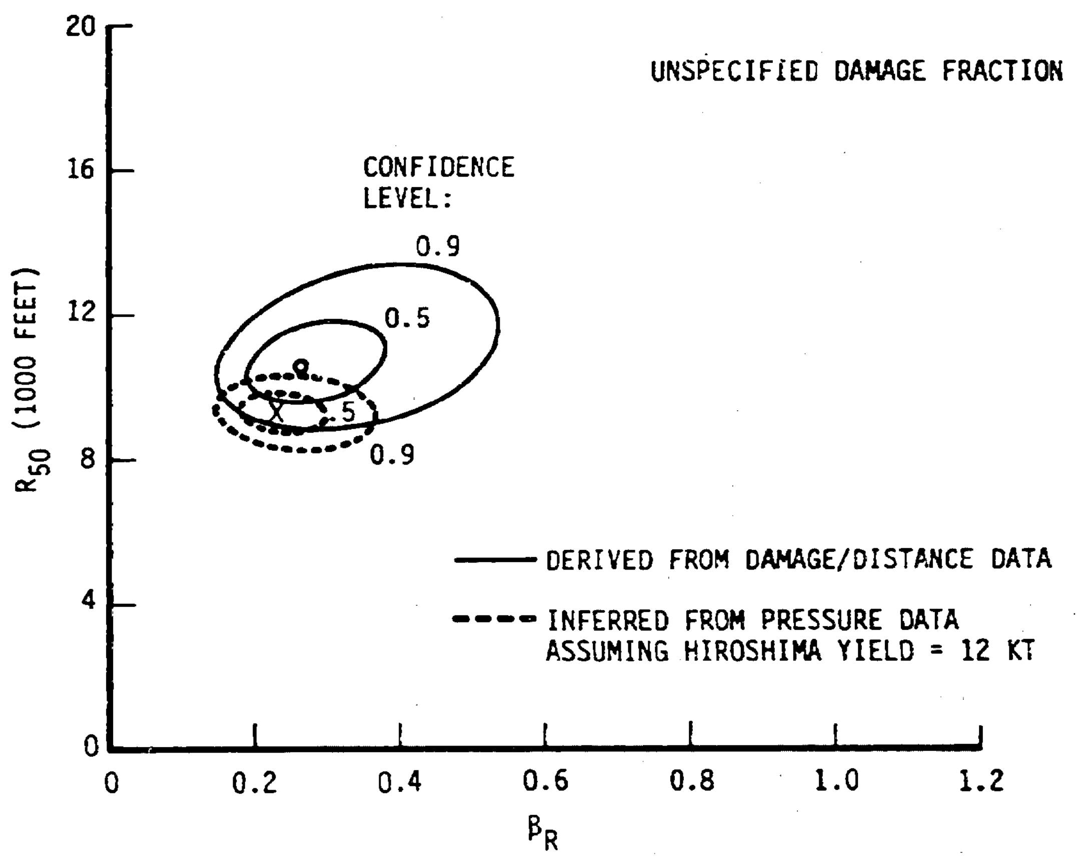


FIGURE 26h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI

SUPERFICIAL DAMAGE CRITERIA

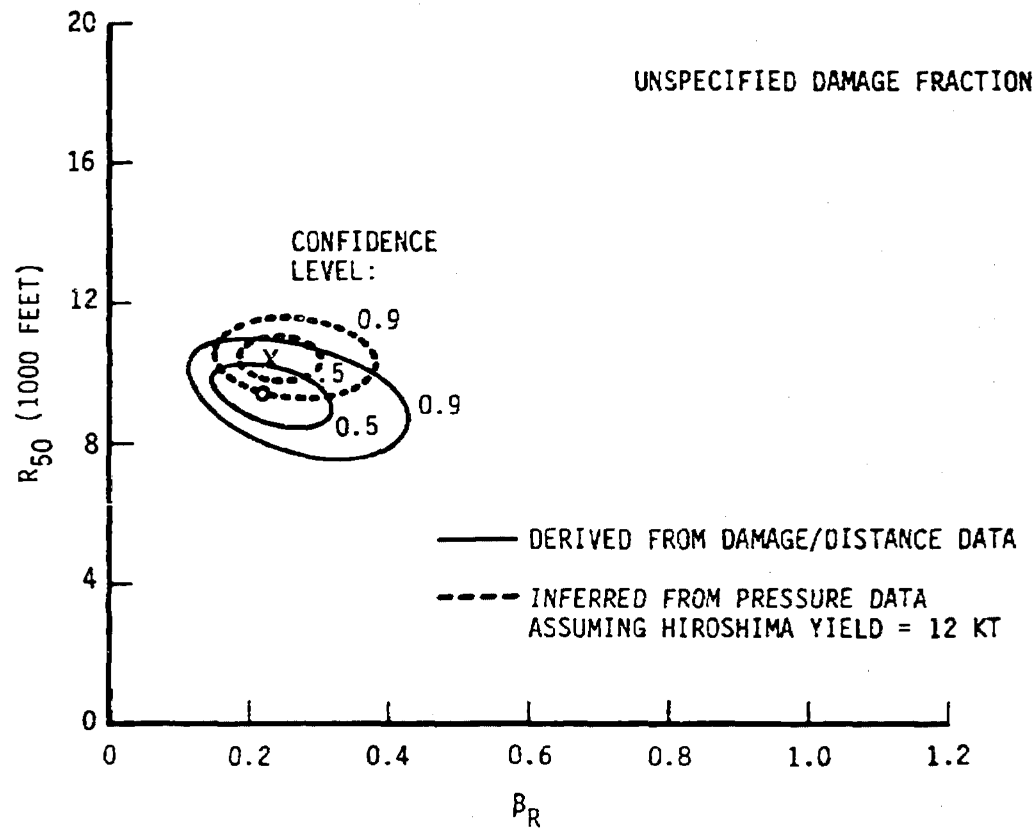


FIGURE 27a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA
I-BEAM OR LATTICE STEEL COLUMNS
STRUCTURAL DAMAGE TO WALLS

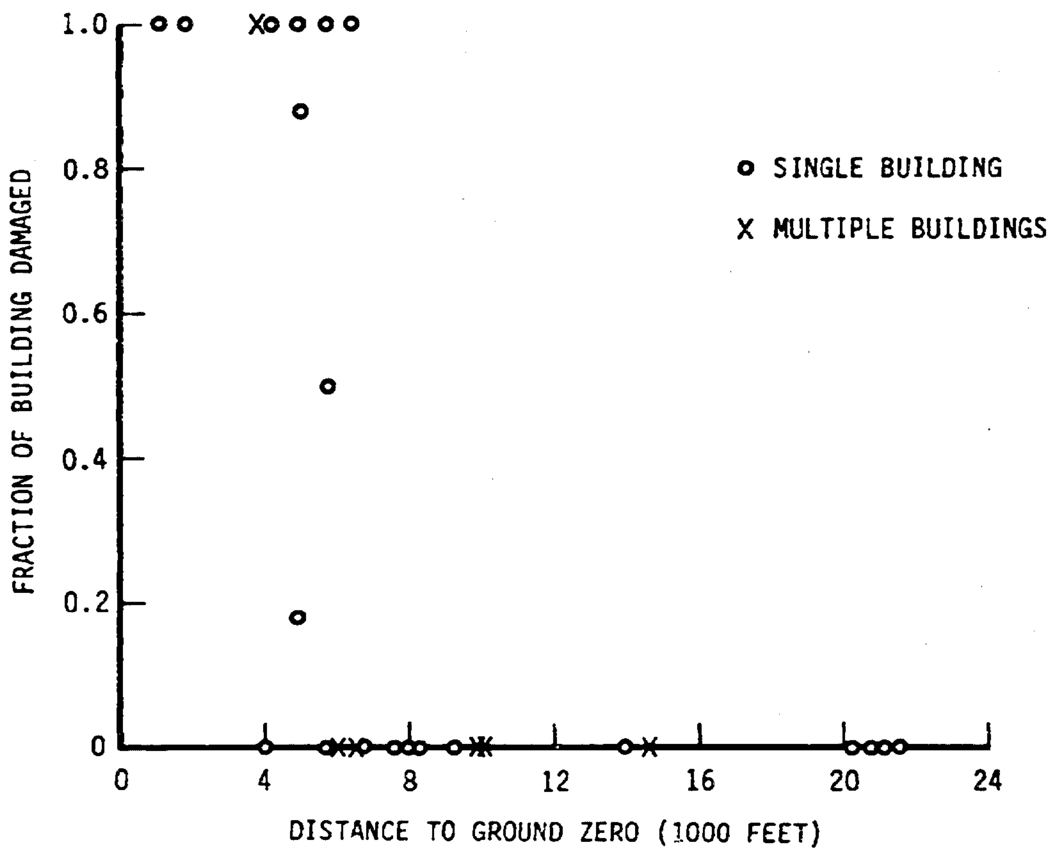


FIGURE 27b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI
I-BEAM OR LATTICE STEEL COLUMNS
STRUCTURAL DAMAGE TO WALLS

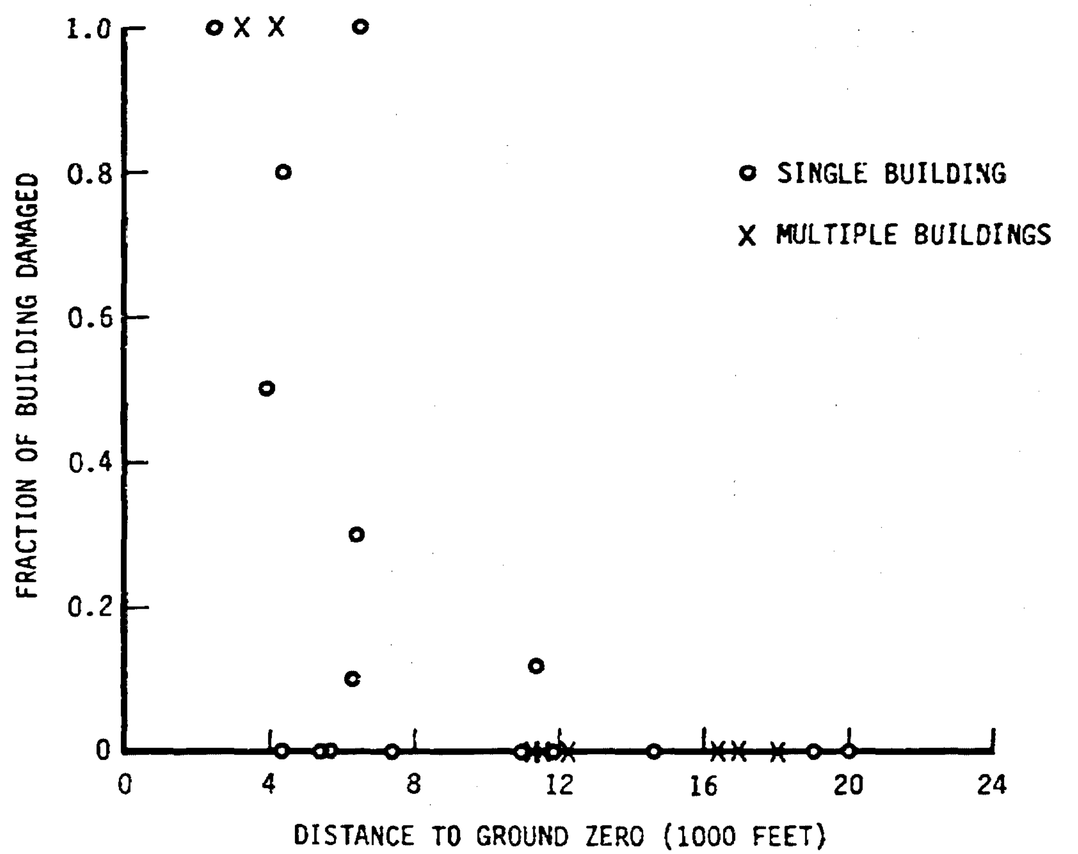


FIGURE 27c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA

I-BEAM OR LATTICE STEEL COLUMNS

STRUCTURAL DAMAGE TO WALLS

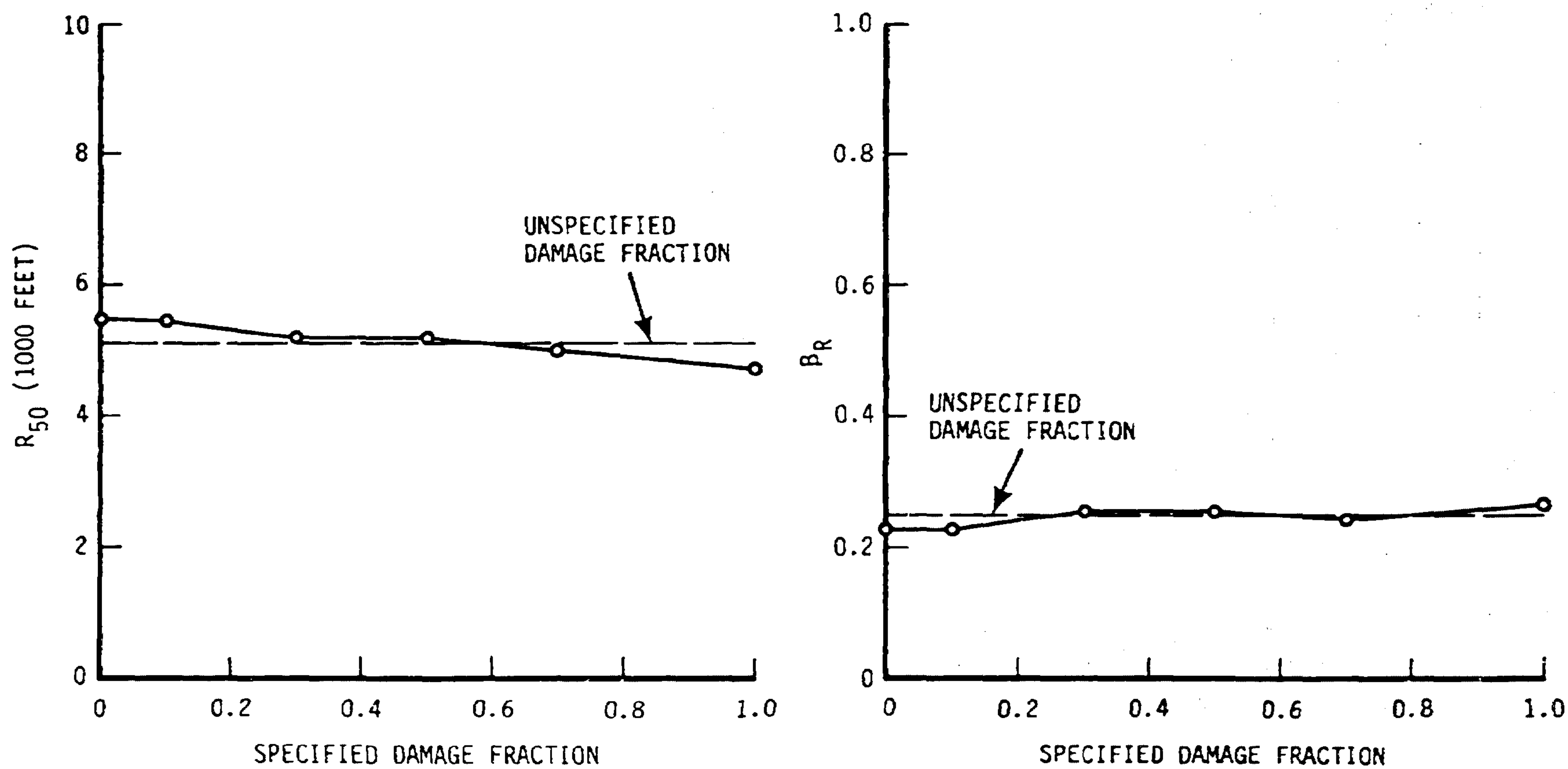


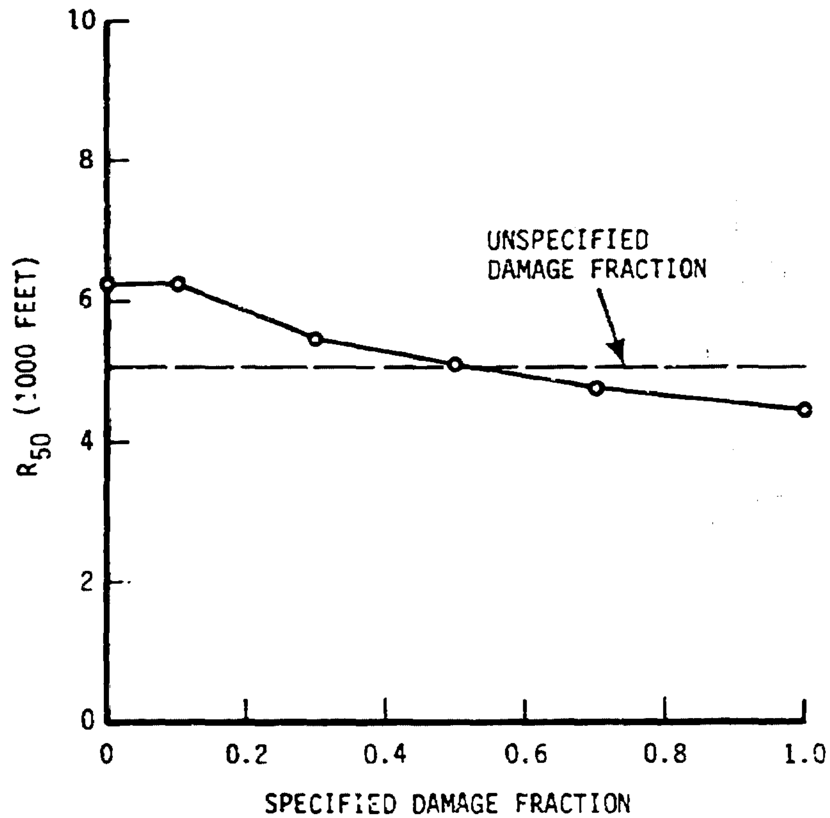
FIGURE 27d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI

I-BEAM OR LATTICE STEEL COLUMNS

STRUCTURAL DAMAGE TO WALLS



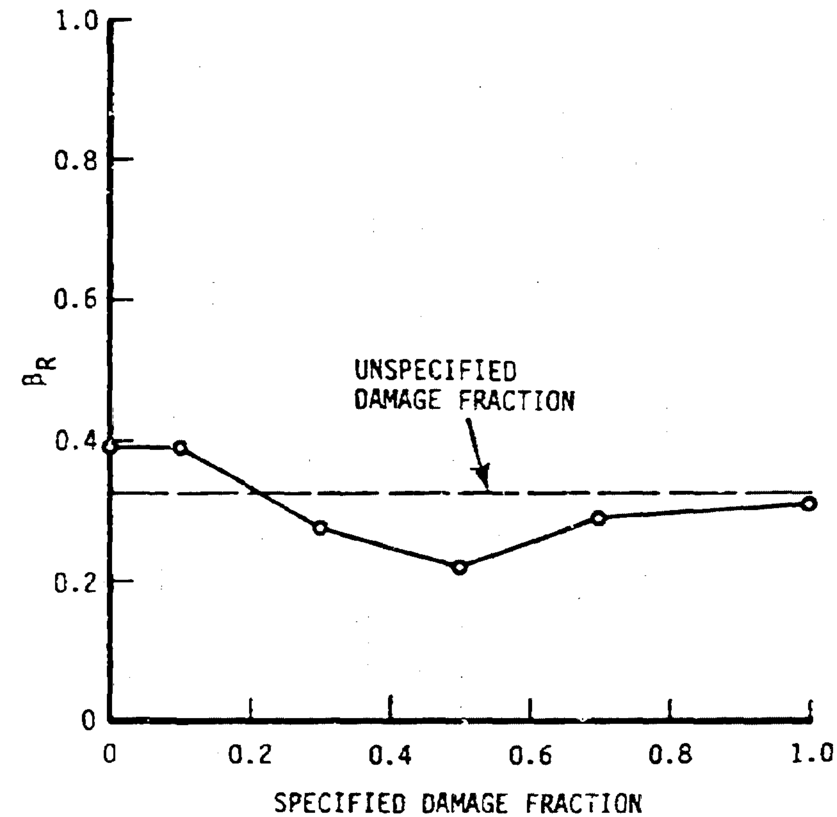


FIGURE 27e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF Q_{50} AND β_Q

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS

I-BEAM OR LATTICE STEEL COLUMNS

STRUCTURAL DAMAGE TO WALLS

HIROSHIMA YIELD ASSUMED = 12 KT

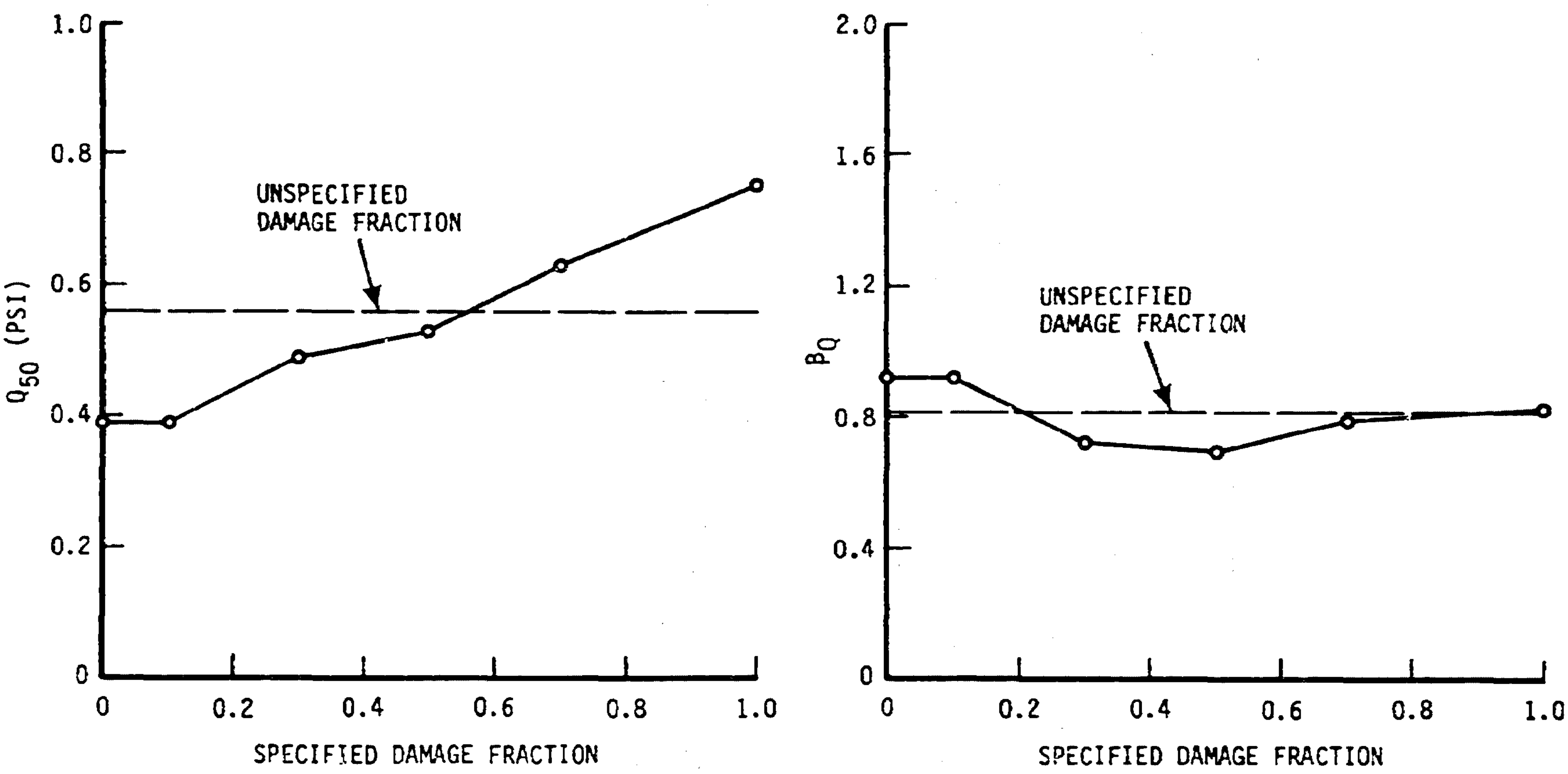


FIGURE 27f

CONFIDENCE REGIONS FOR Q_{50} AND β_Q

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS

I-BEAM OR LATTICE STEEL COLUMNS

STRUCTURAL DAMAGE TO WALLS

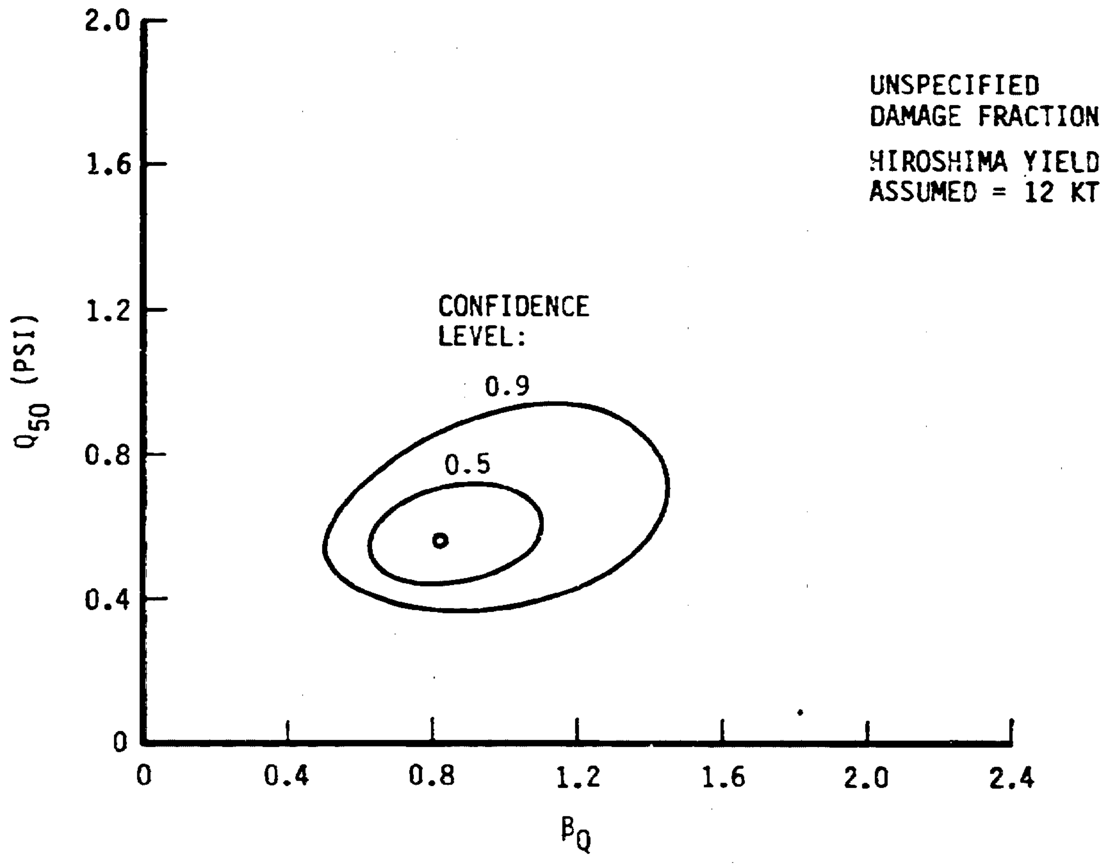


FIGURE 27g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA
I-BEAM OR LATTICE STEEL COLUMNS
STRUCTURAL DAMAGE TO WALLS

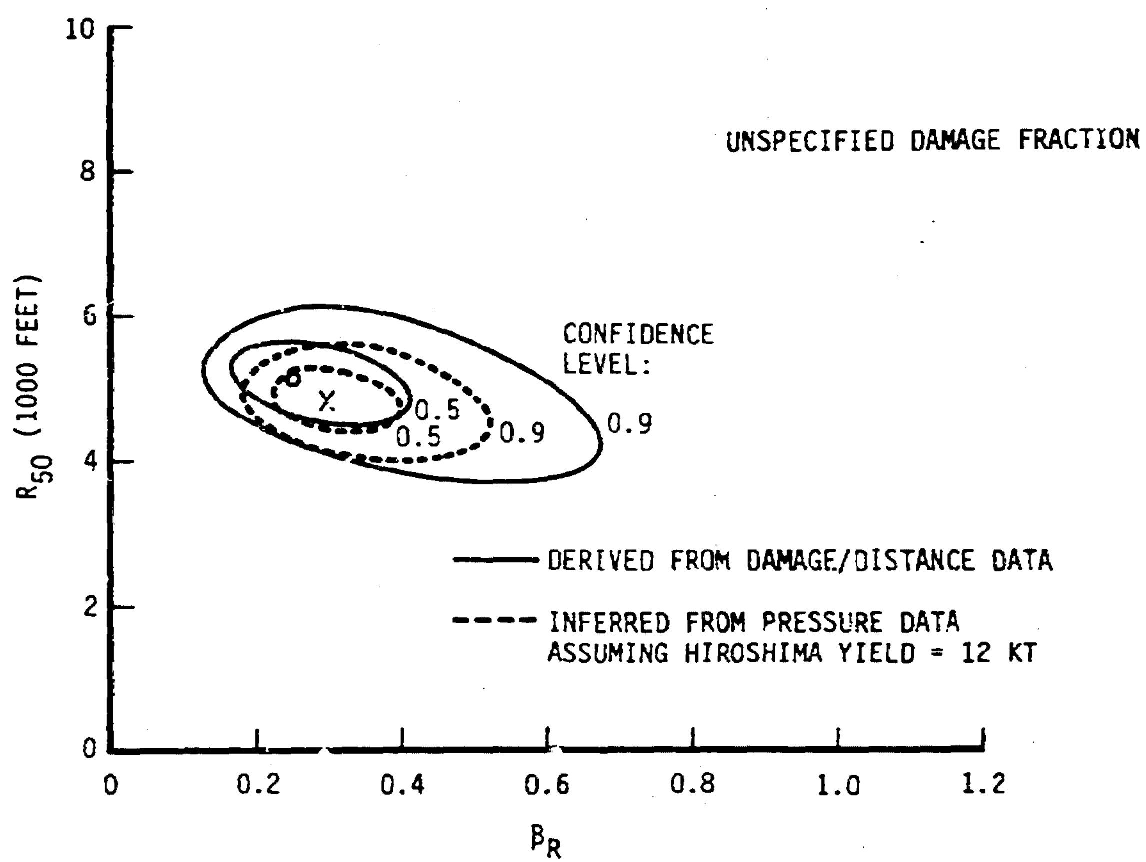


FIGURE 27h

CONFIDENCE REGIONS FOR R_{5U} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI

I-BEAM OR LATTICE STEEL COLUMNS

STRUCTURAL DAMAGE TO WALLS

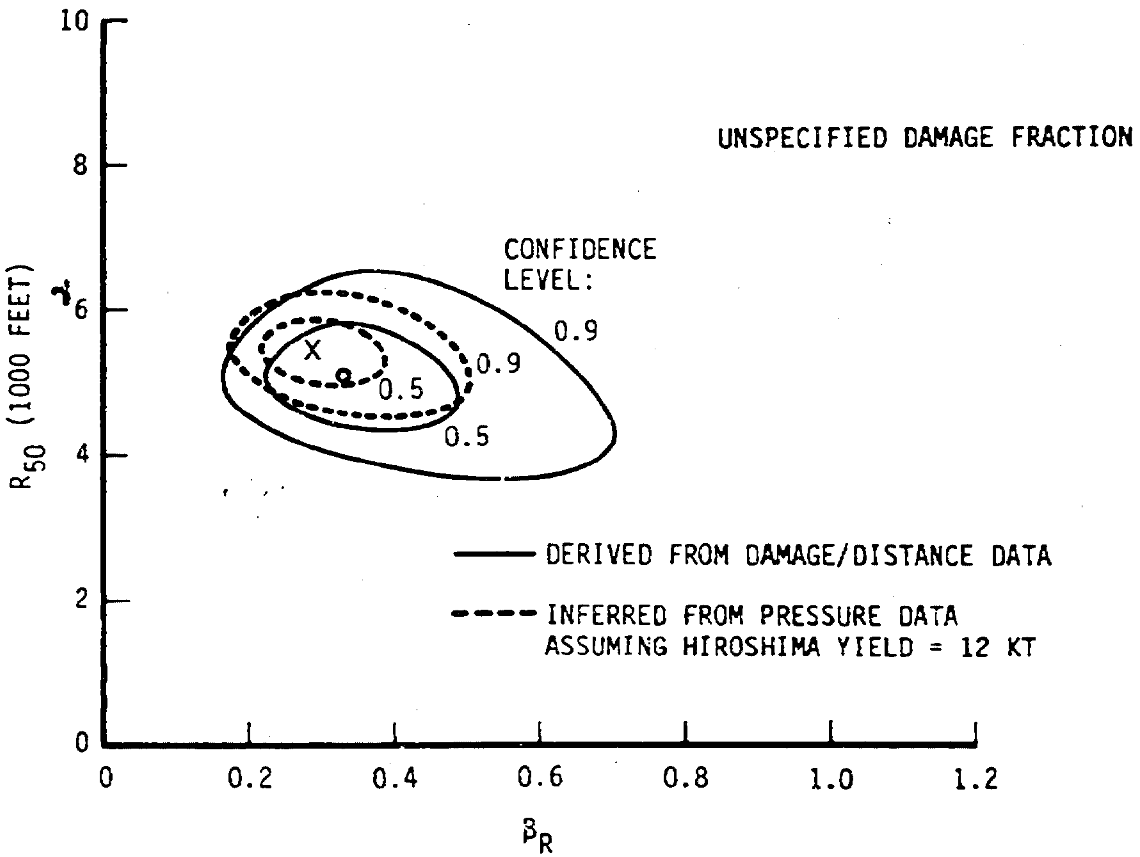


FIGURE 28a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA
WALL COVER MATERIAL FAILS SLOWLY
STRUCTURAL DAMAGE TO WALLS

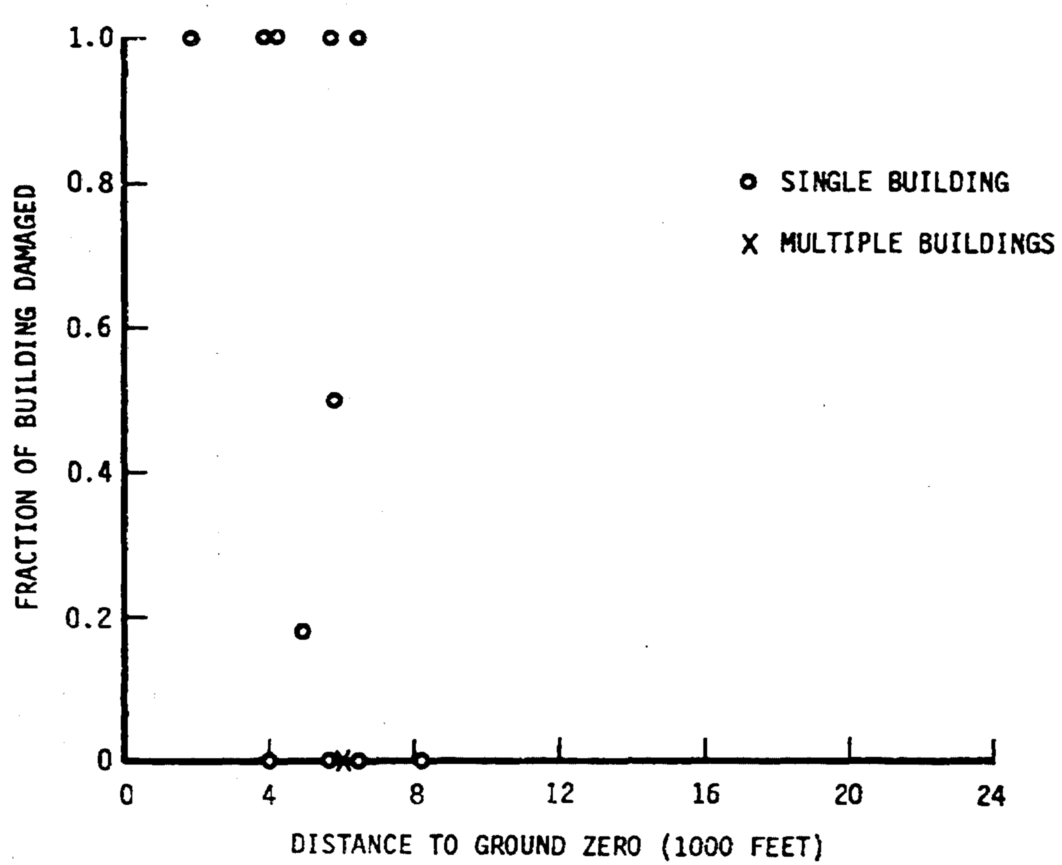


FIGURE 28b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI
WALL COVER MATERIAL FAILS SLOWLY
STRUCTURAL DAMAGE TO WALLS

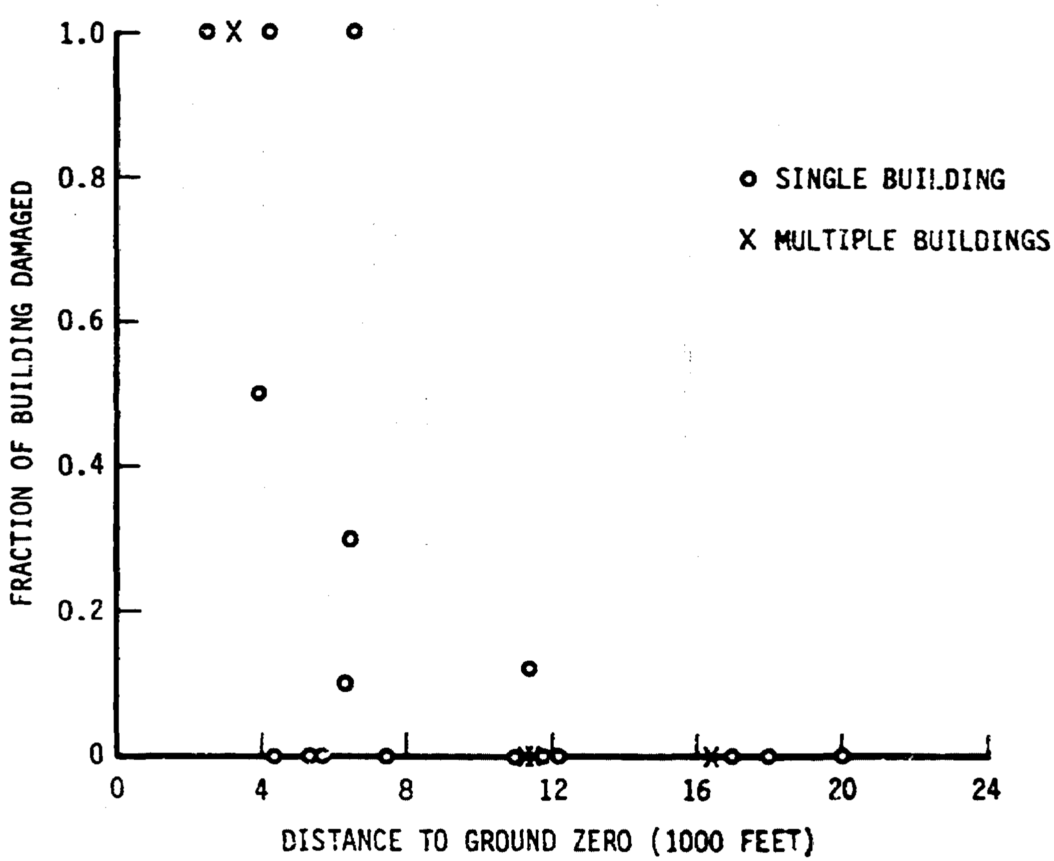


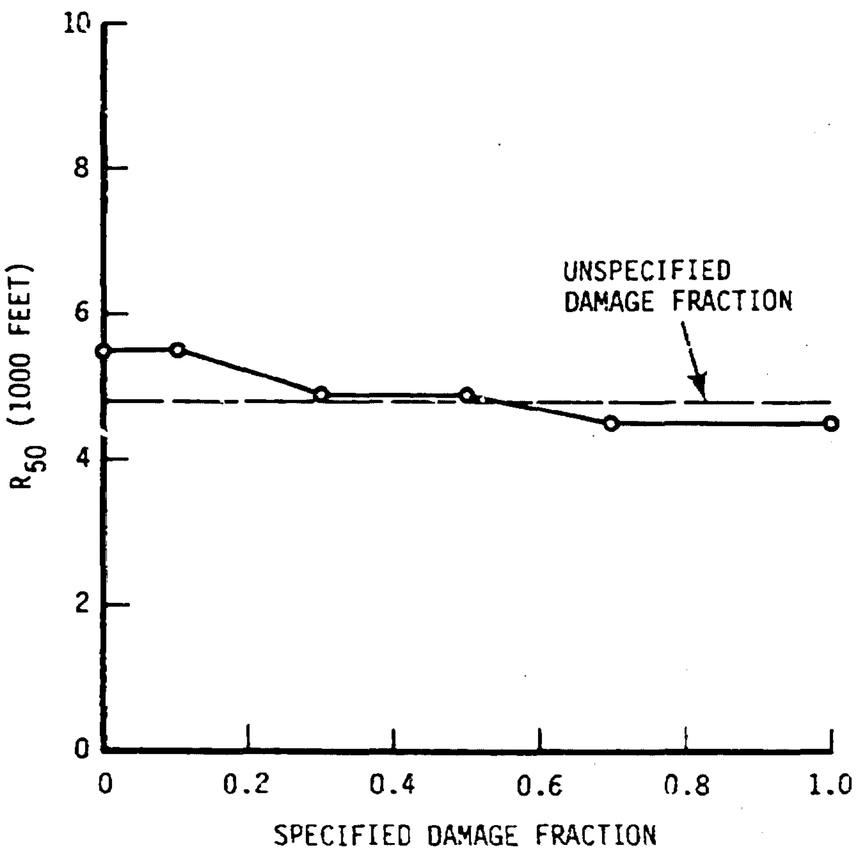
FIGURE 28c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA

WALL COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO WALLS



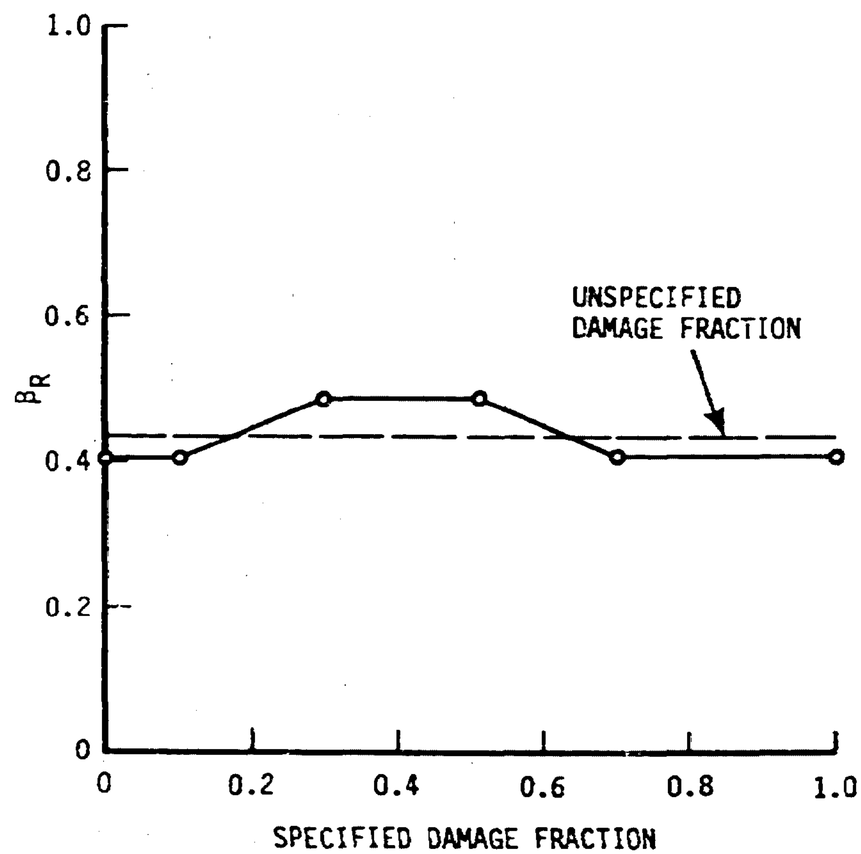


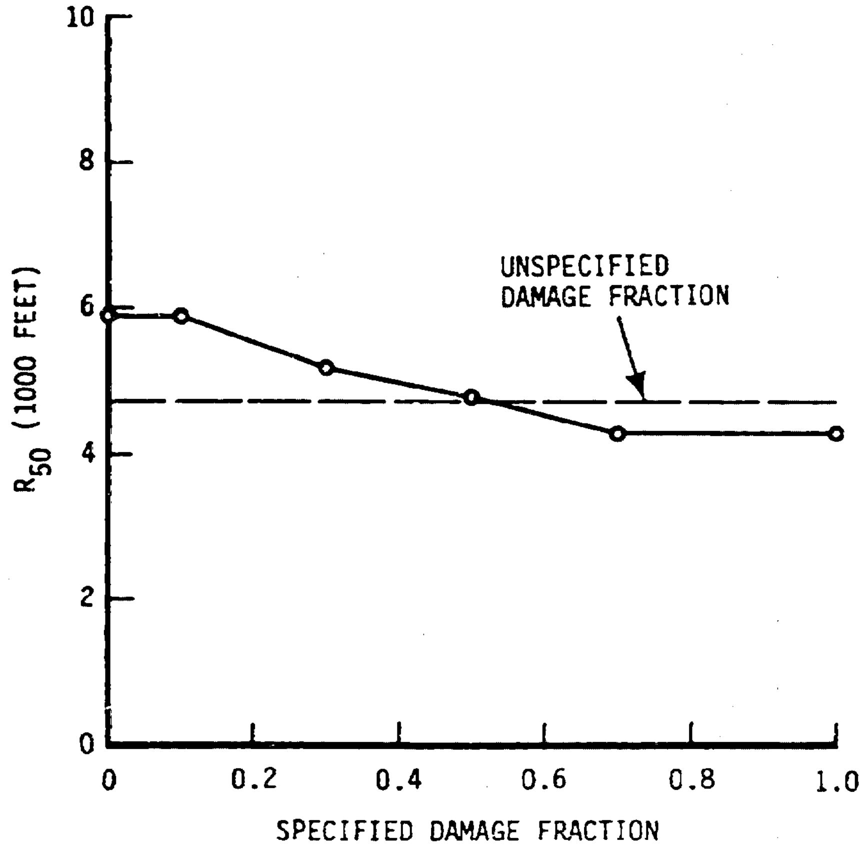
FIGURE 28d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI

WALL COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO WALLS



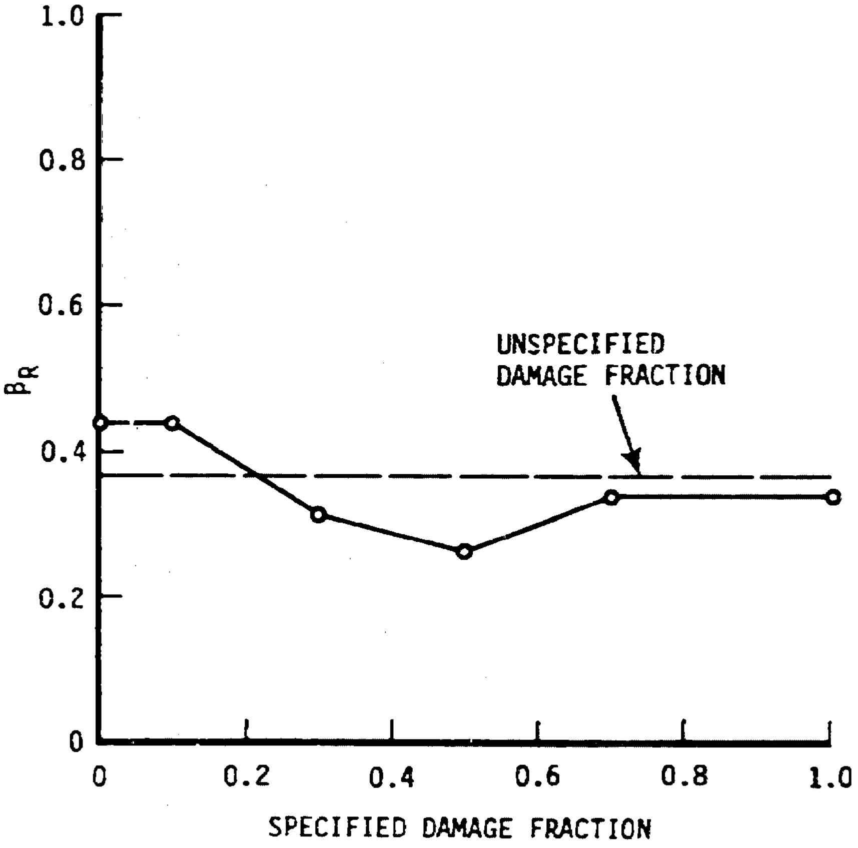


FIGURE 28e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF Q_{50} AND β_Q

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS

WALL COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO WALLS

HIROSHIMA YIELD ASSUMED = 12 KT

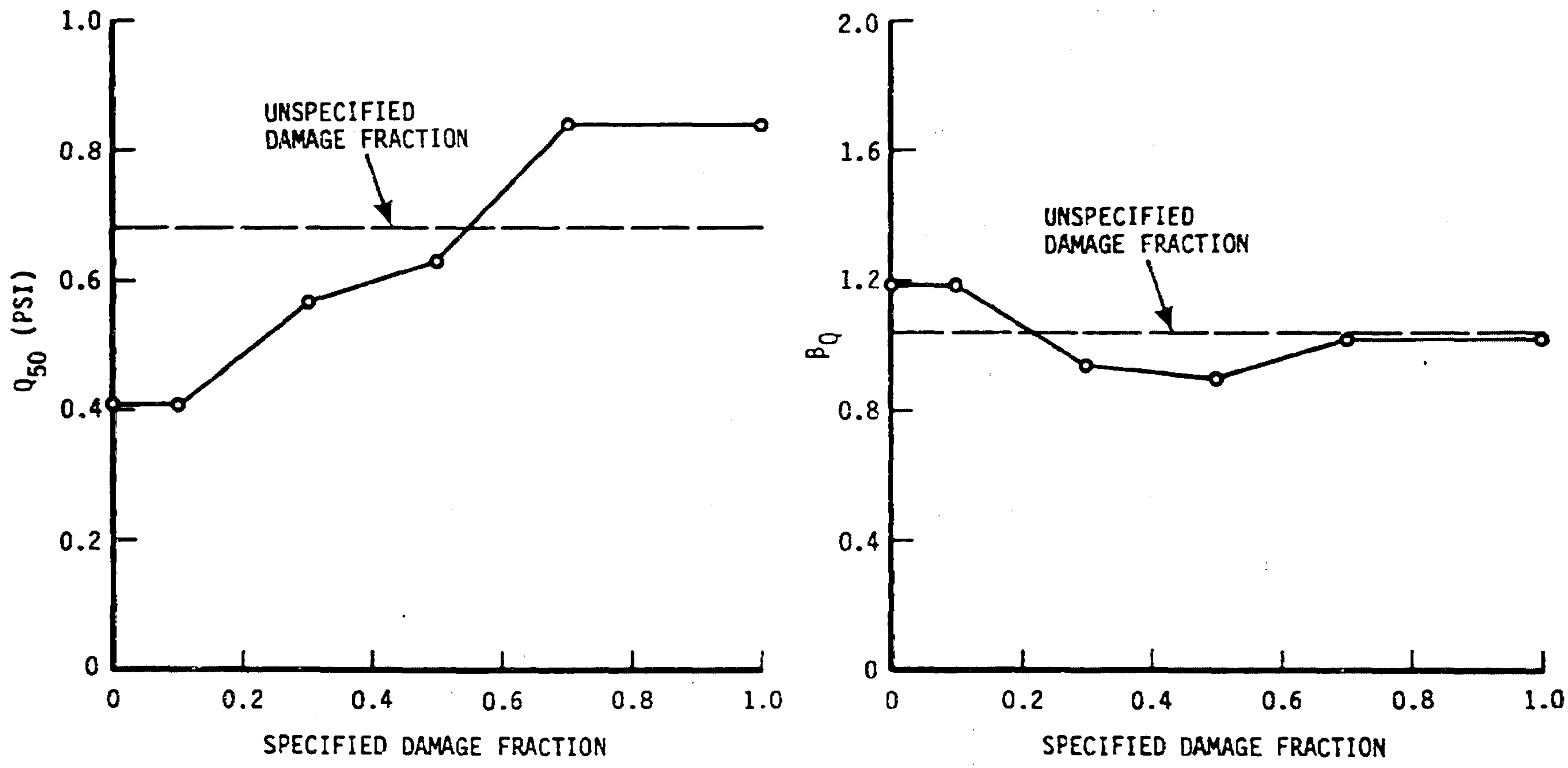


FIGURE 28f

CONFIDENCE REGIONS FOR Q_{50} AND β_Q

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS

WALL COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO WALLS

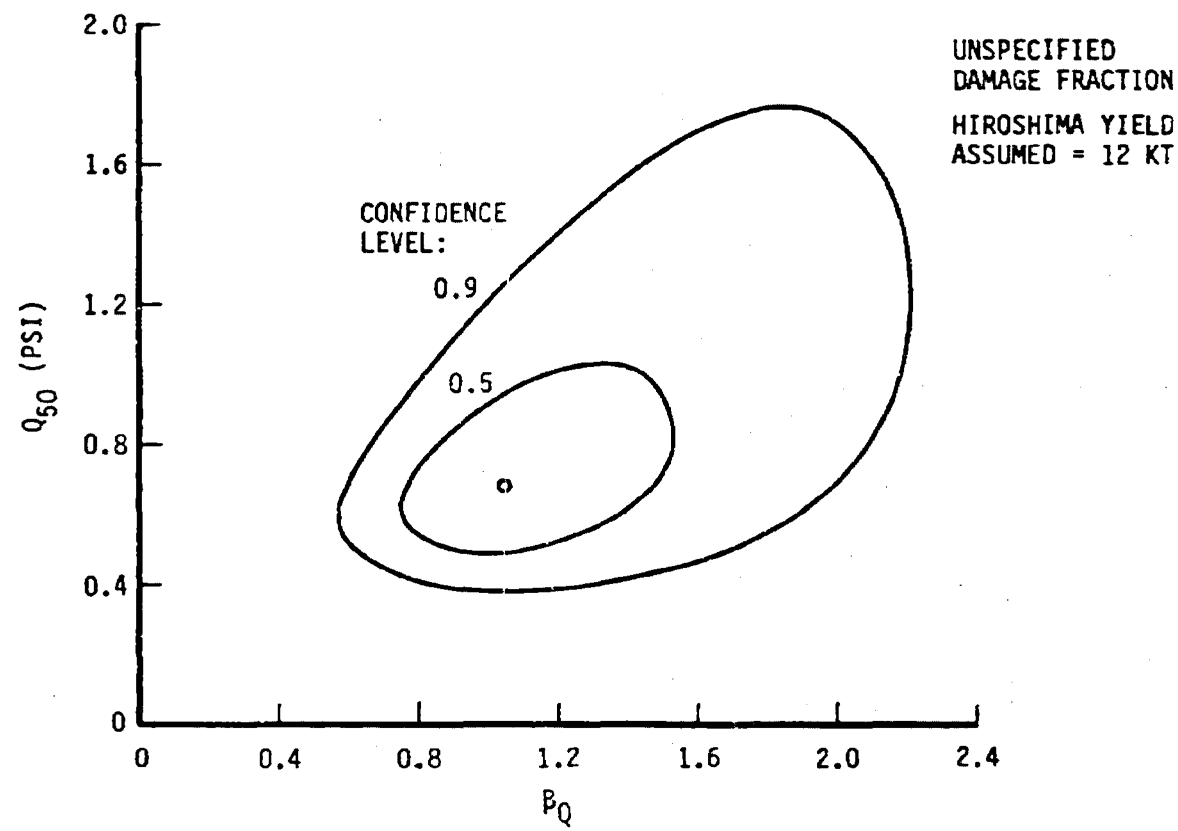


FIGURE 28g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA

WALL COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO WALLS

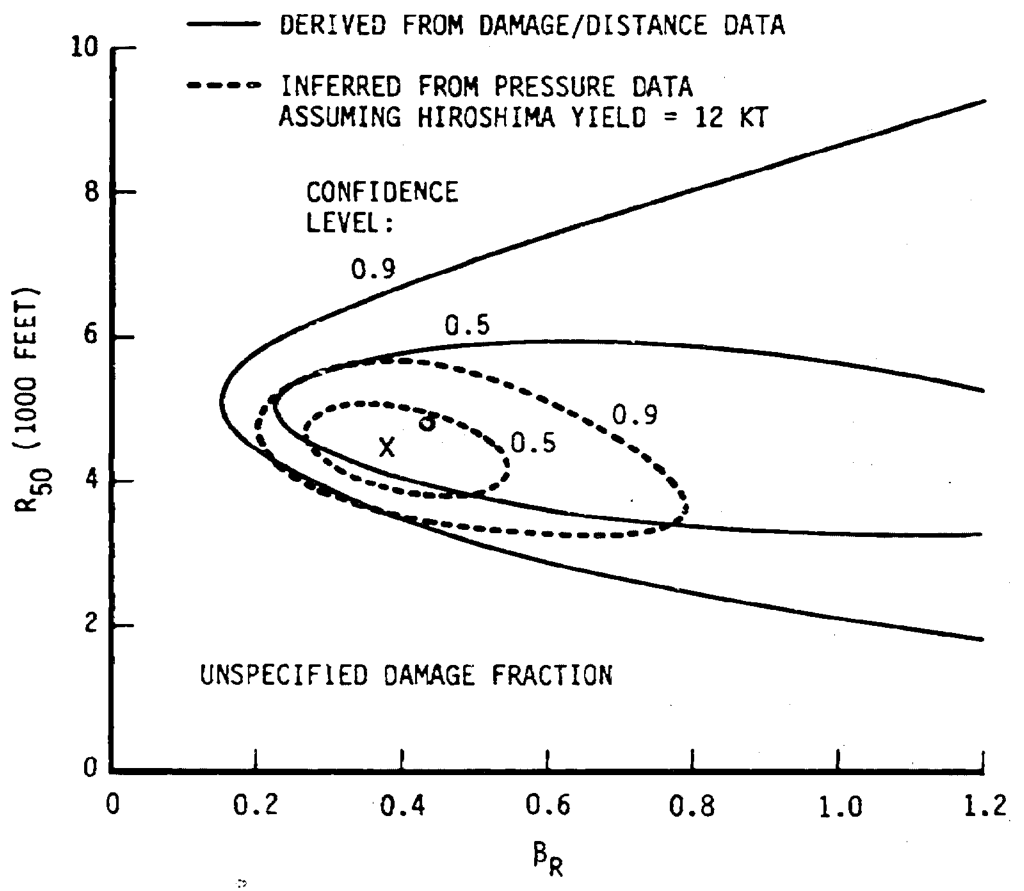


FIGURE 28h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI

WALL COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO WALLS

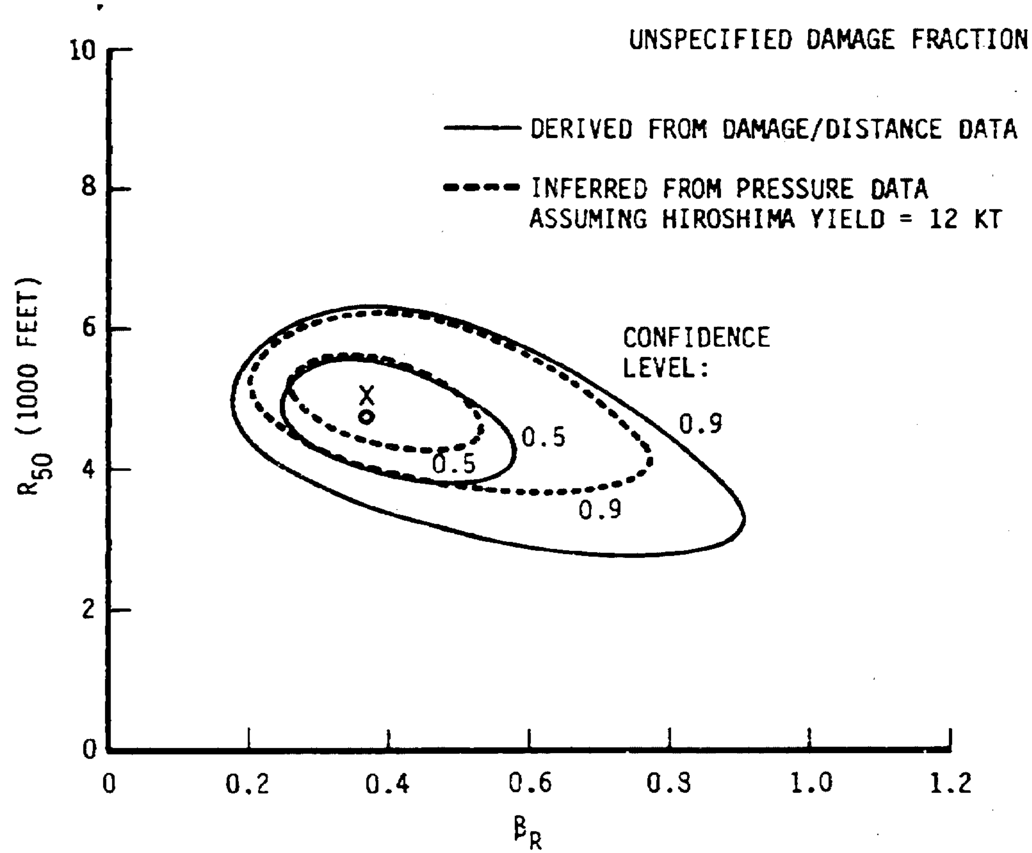


FIGURE 29a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA
ALL WALL TYPES EXCEPT CONCRETE; STEEL ROOF TRUSSES
STRUCTURAL DAMAGE TO ROOFS

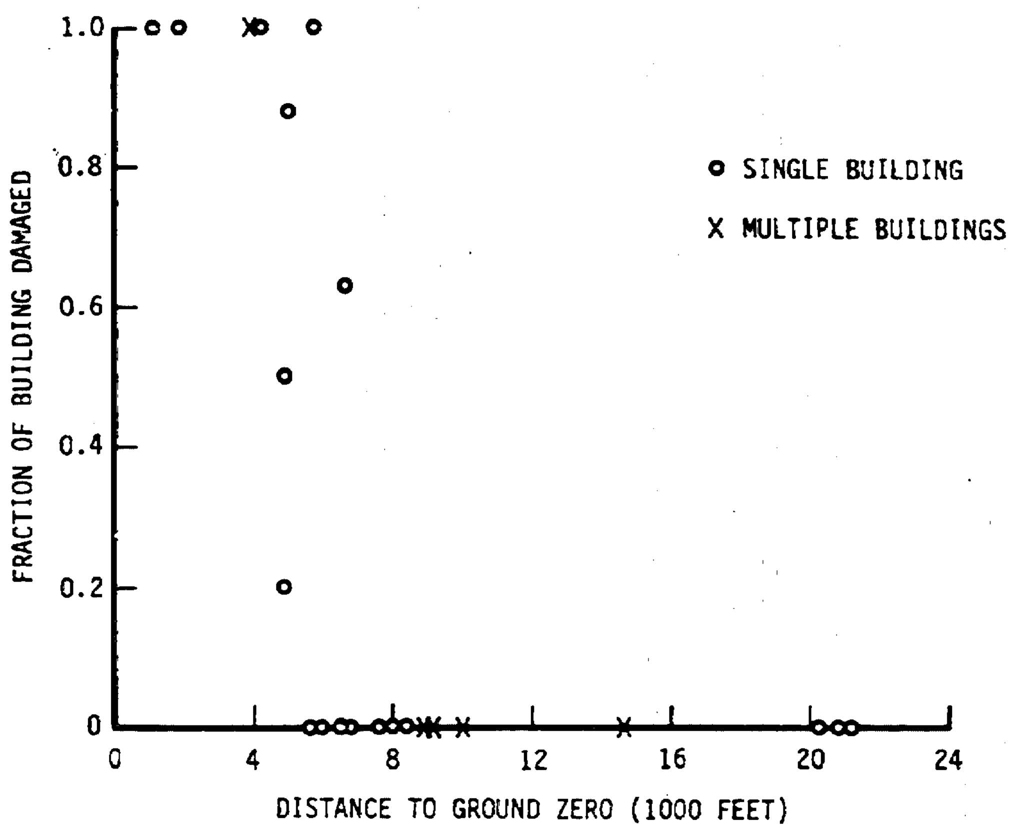


FIGURE 29b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI
ALL WALL TYPES EXCEPT CONCRETE; STEEL ROOF TRUSSES
STRUCTURAL DAMAGE TO ROOFS

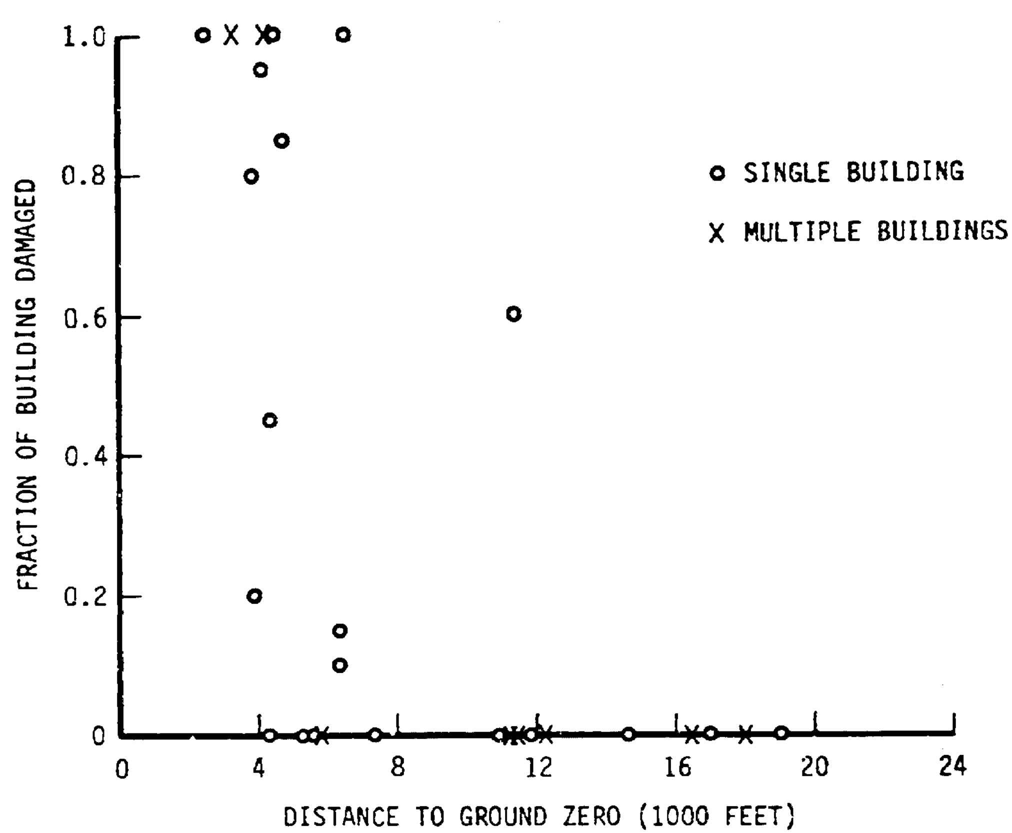


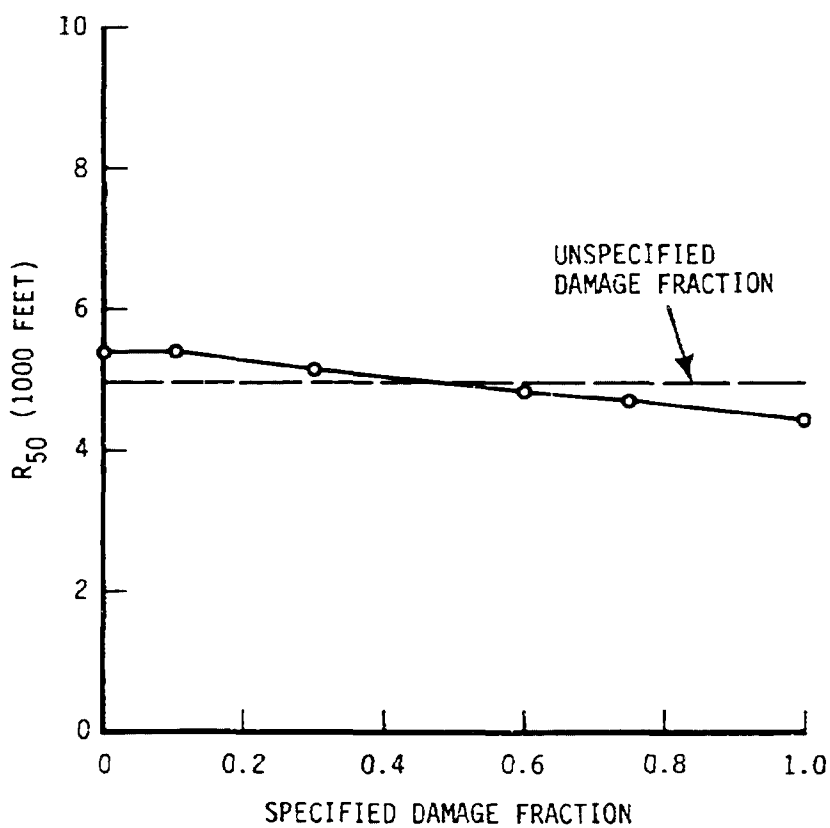
FIGURE 29c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA

ALL WALL TYPES EXCEPT CONCRETE; STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS



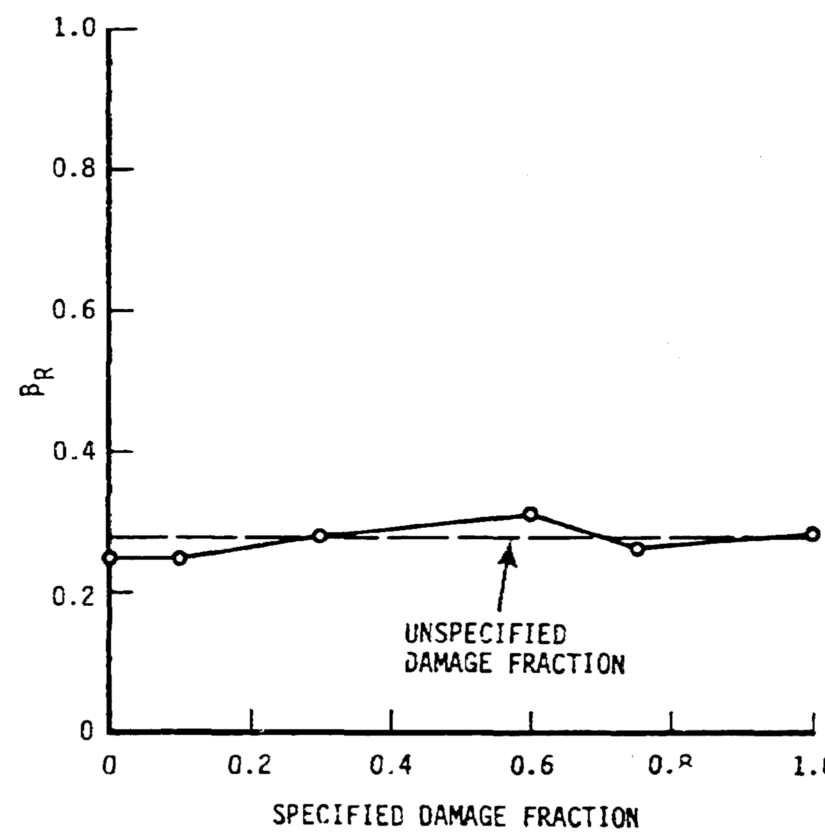
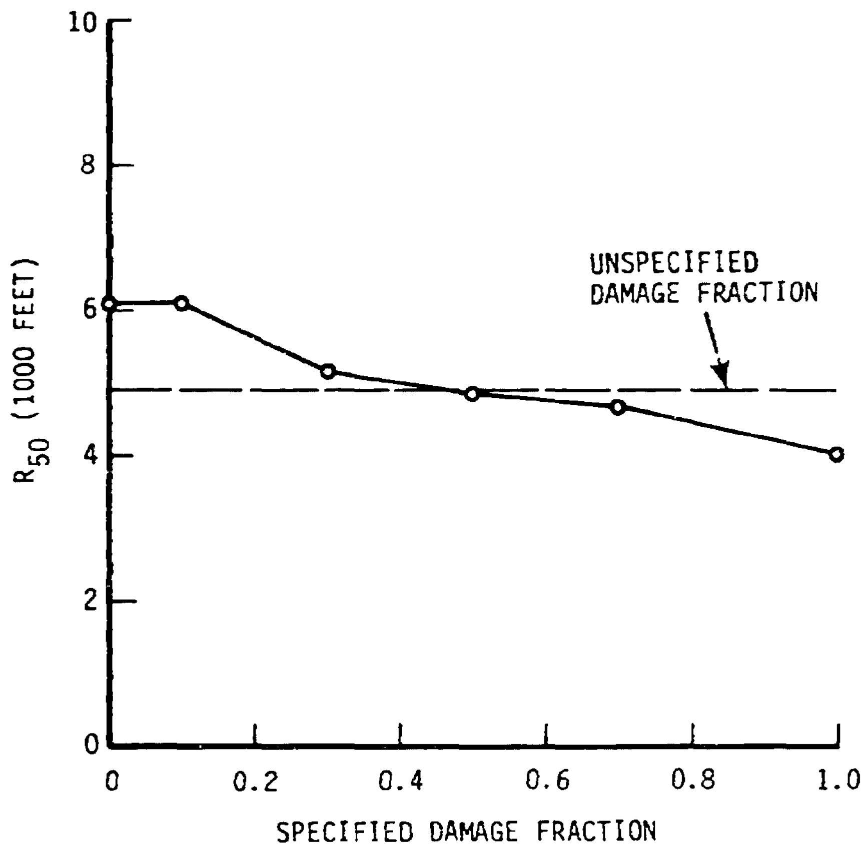


FIGURE 29d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI
ALL WALL TYPES EXCEPT CONCRETE; STEEL ROOF TRUSSES
STRUCTURAL DAMAGE TO ROOFS



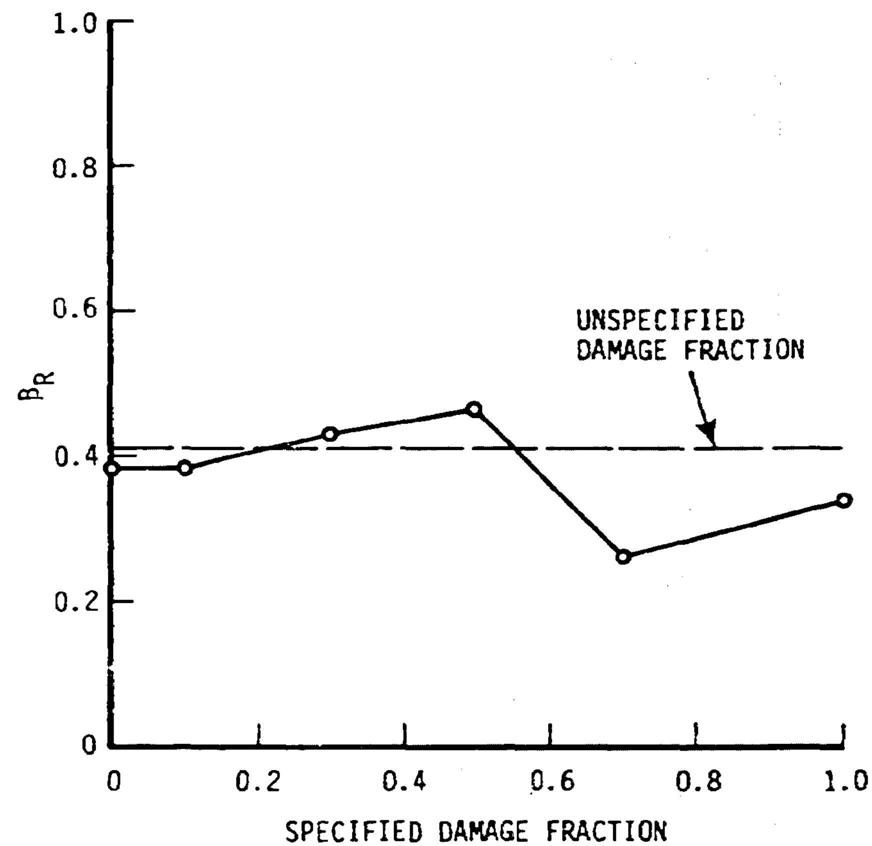


FIGURE 29e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF Q_{50} AND β_Q

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS

ALL WALL TYPES EXCEPT CONCRETE; STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

HIROSHIMA YIELD ASSUMED = 12 KT

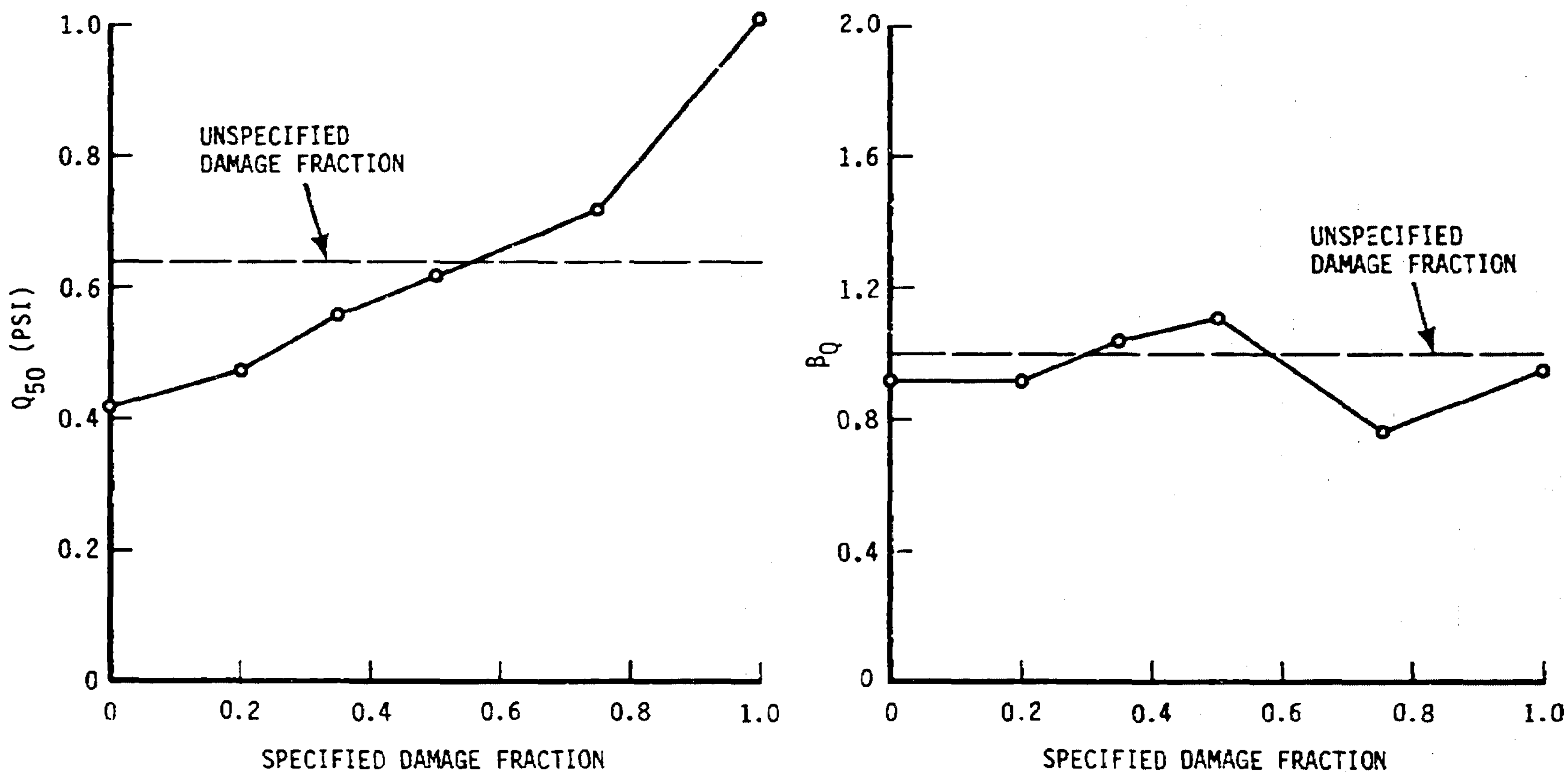


FIGURE 29f

CONFIDENCE REGIONS FOR Q_{50} AND β_Q

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS

ALL WALL TYPES EXCEPT CONCRETE; STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

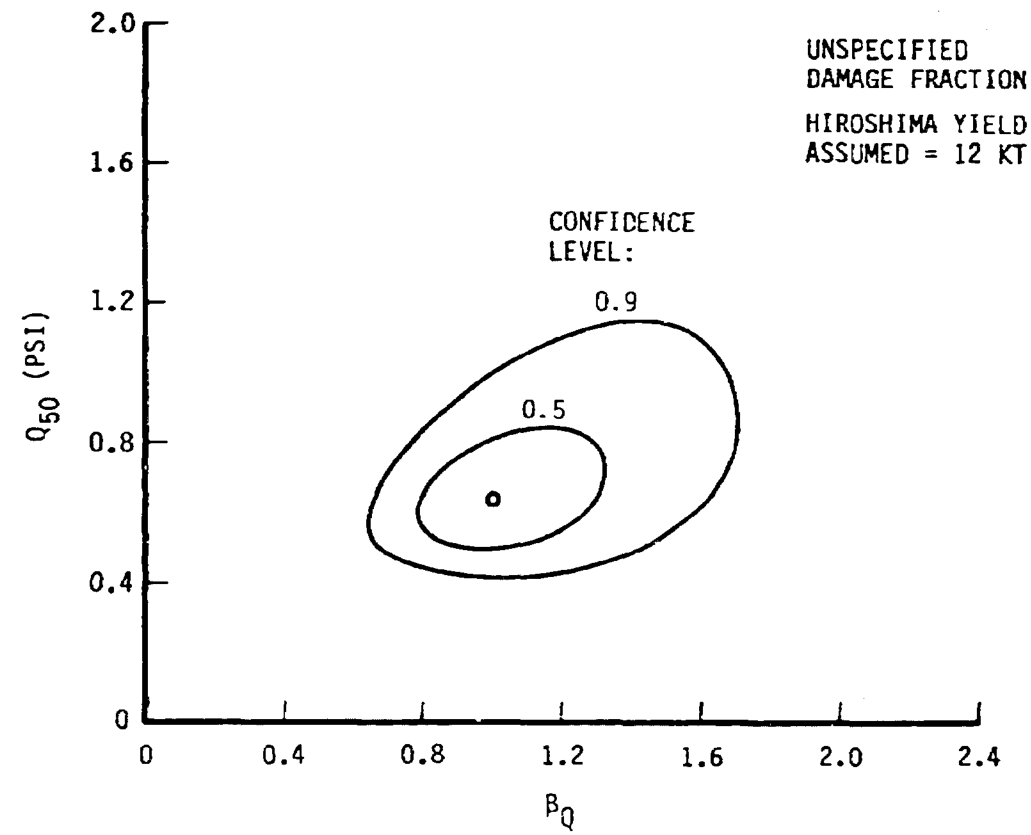


FIGURE 29g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA

ALL WALL TYPES EXCEPT CONCRETE; STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

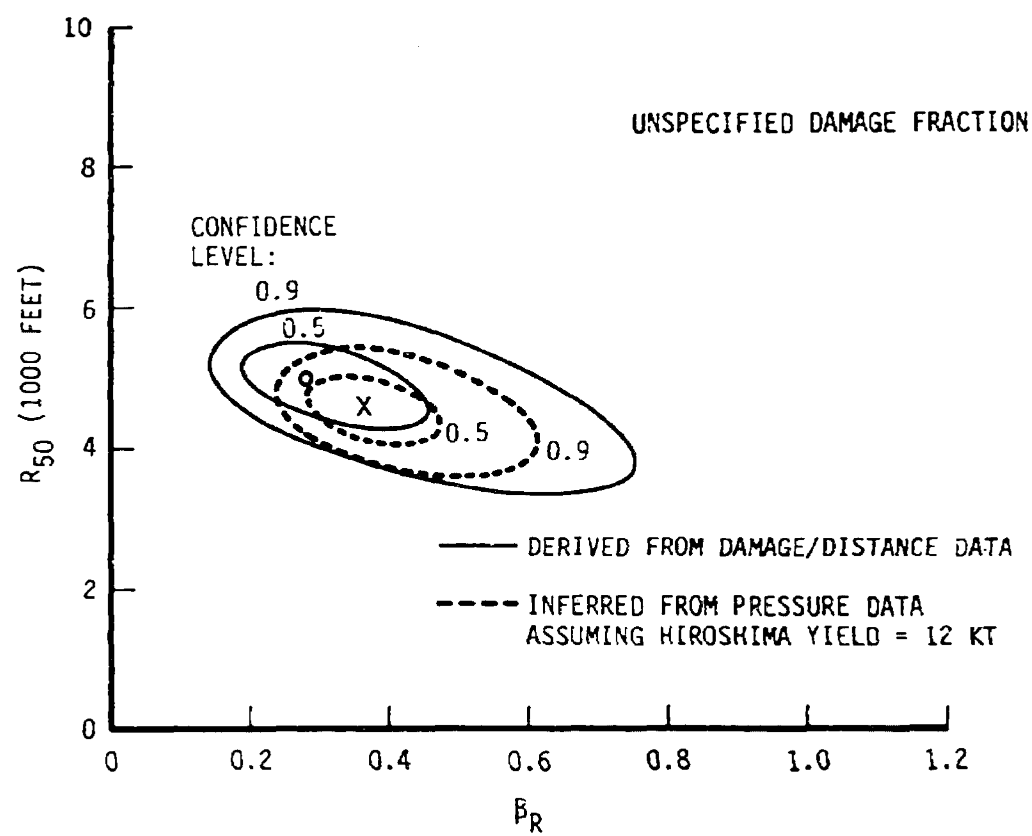


FIGURE 29h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI

ALL WALL TYPES EXCEPT CONCRETE; STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

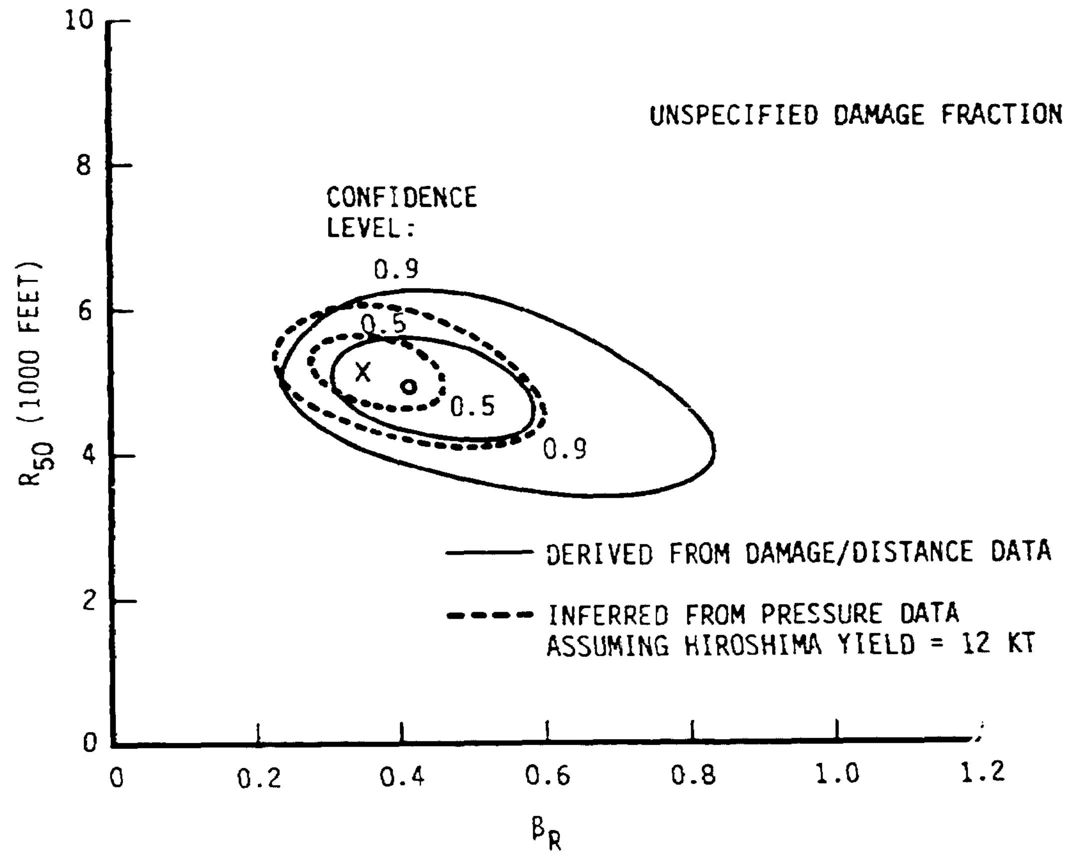


FIGURE 30a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA
STEEL ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY
STRUCTURAL DAMAGE TO ROOFS

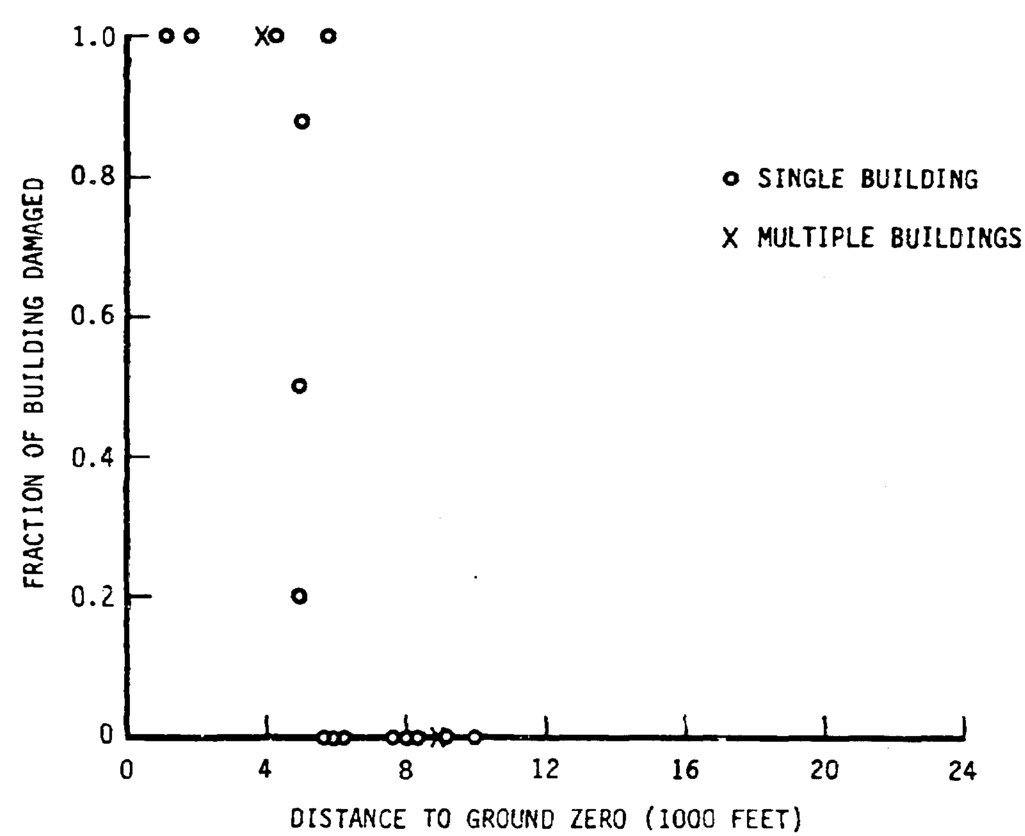


FIGURE 30b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI
STEEL ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY
STRUCTURAL DAMAGE TO ROOFS

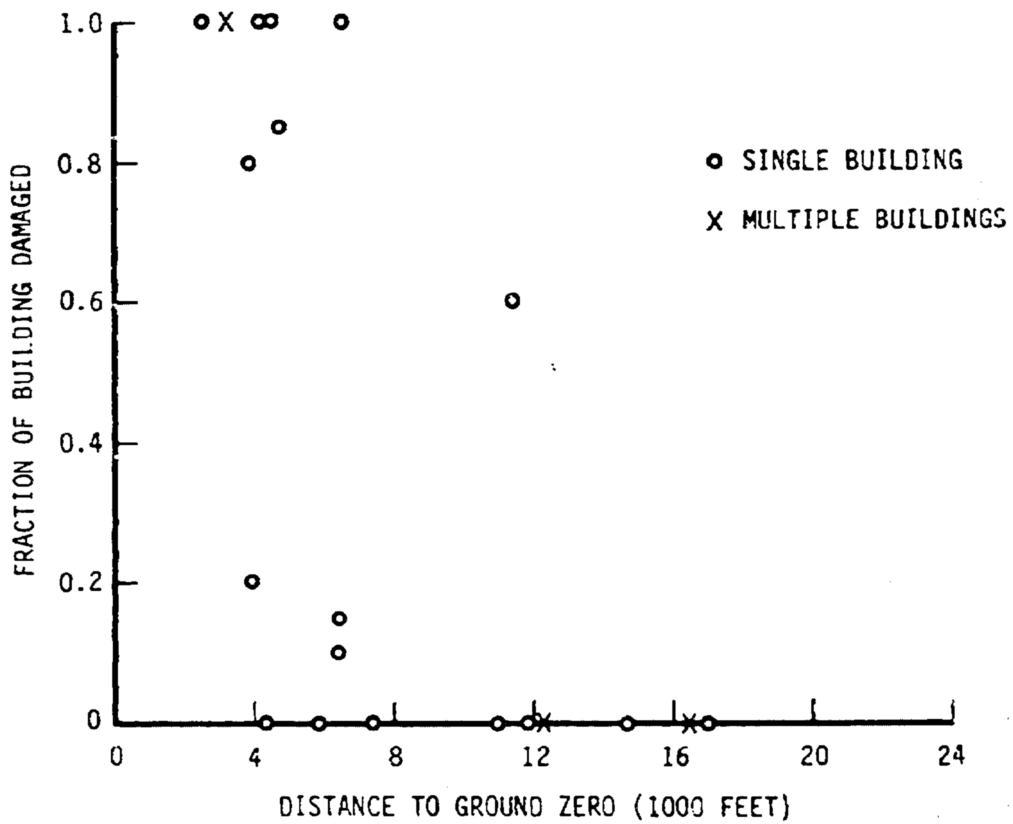


FIGURE 30c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA
STEEL ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY
STRUCTURAL DAMAGE TO ROOFS

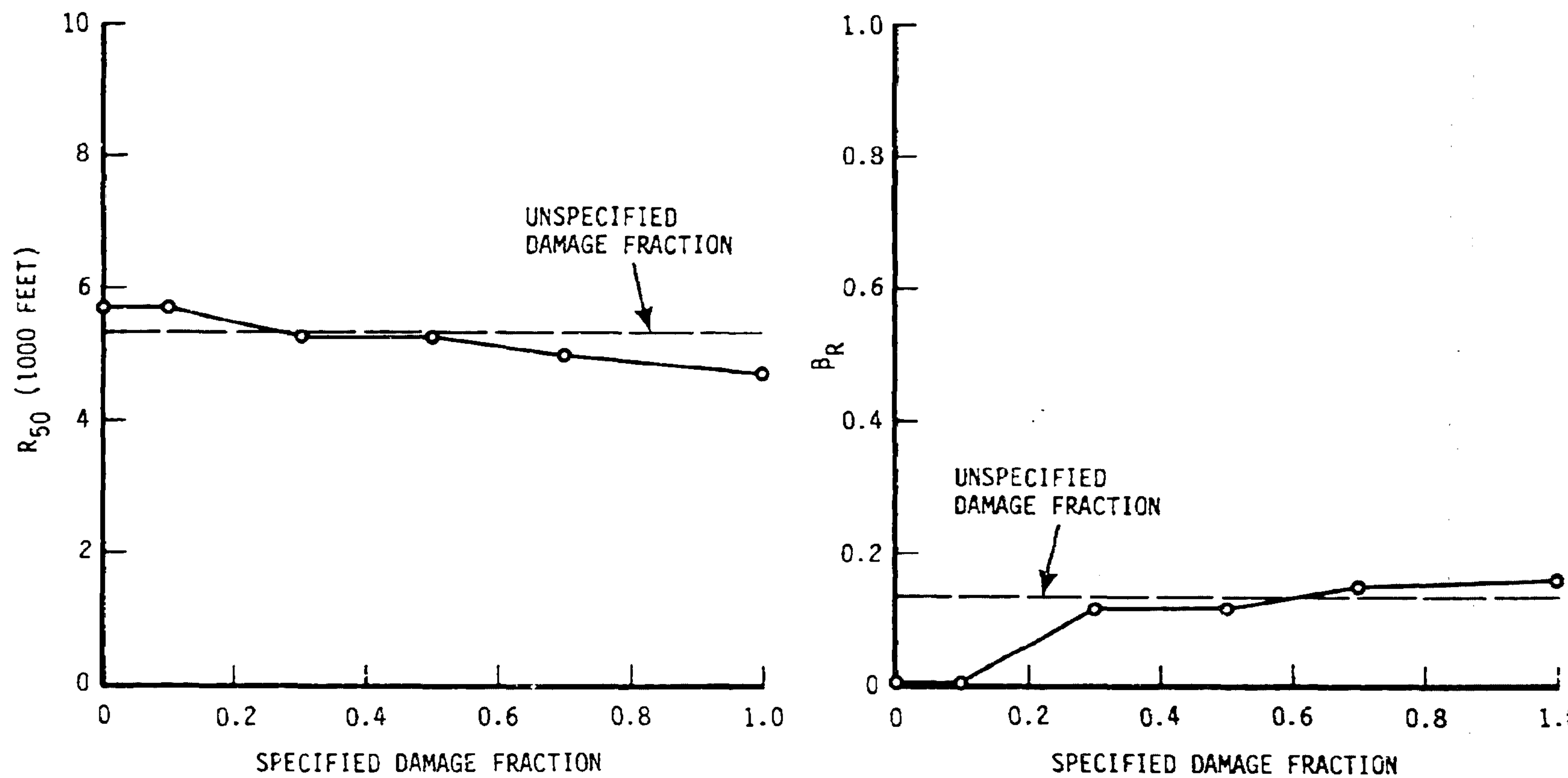


FIGURE 30d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND B_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI
STEEL ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY
STRUCTURAL DAMAGE TO ROOFS

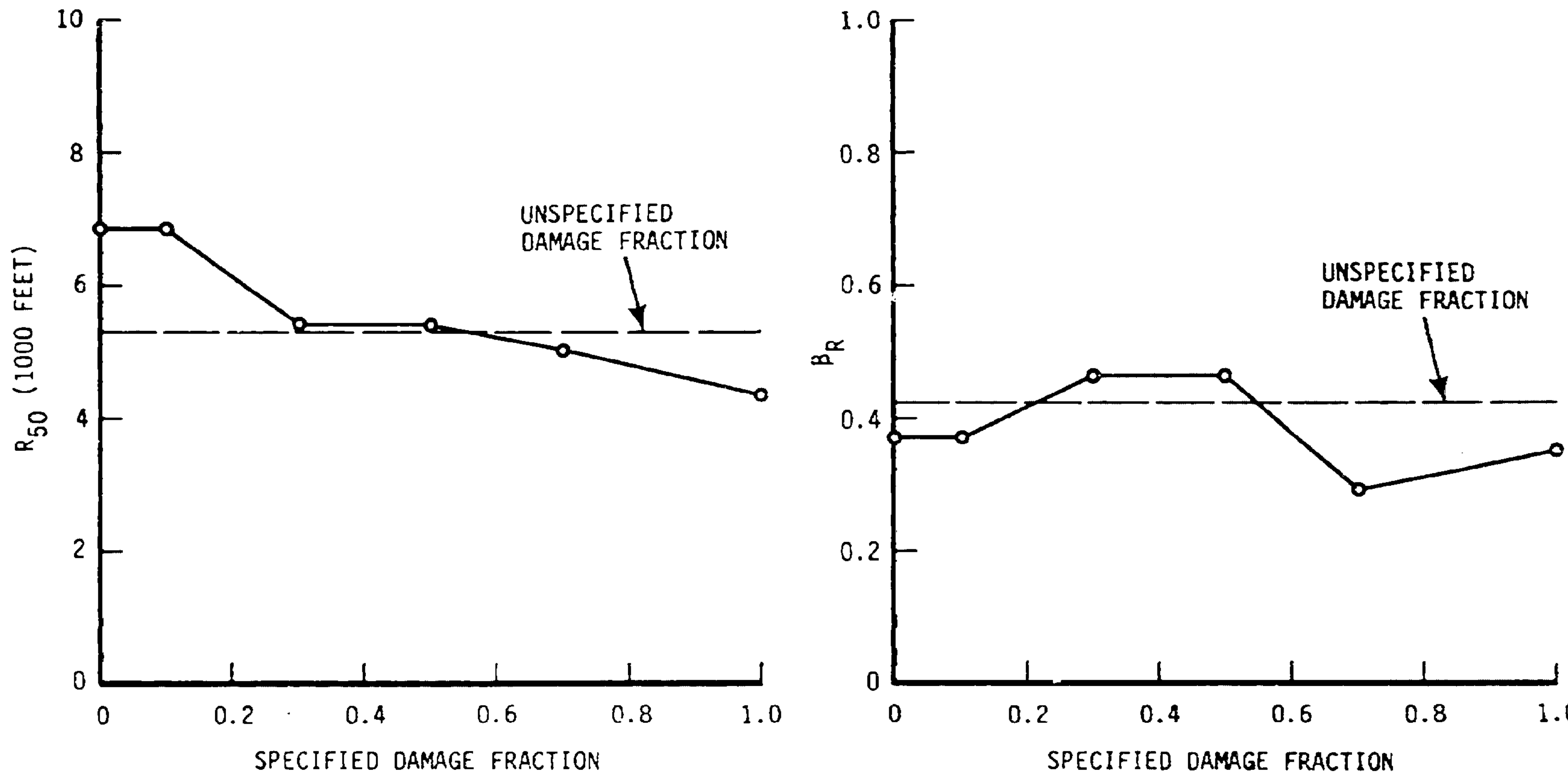


FIGURE 30e

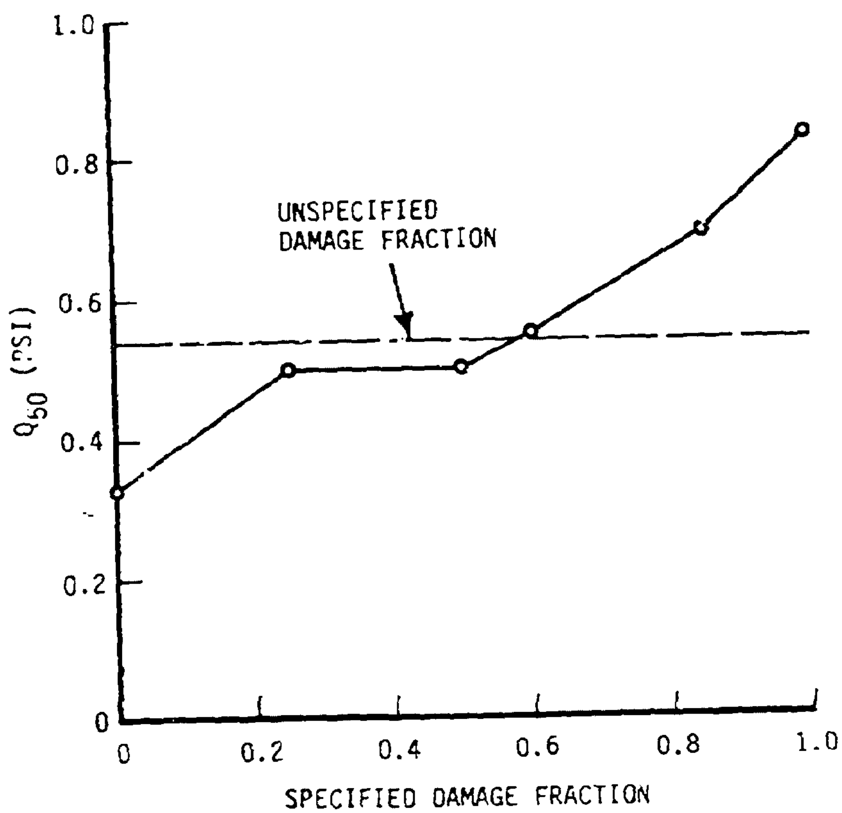
EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF Q_{50} AND B_Q

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS

STEEL ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO ROOFS

HIROSHIMA YIELD ASSUMED = 12 KT



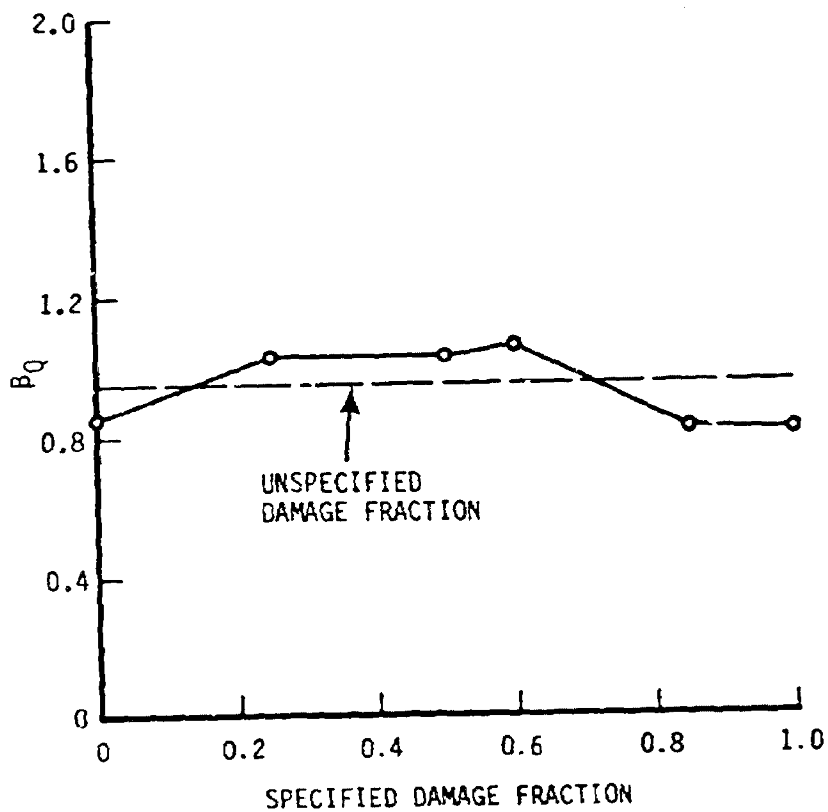


FIGURE 30f

CONFIDENCE REGIONS FOR Q_{50} AND β_Q

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS

STEEL ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO ROOFS

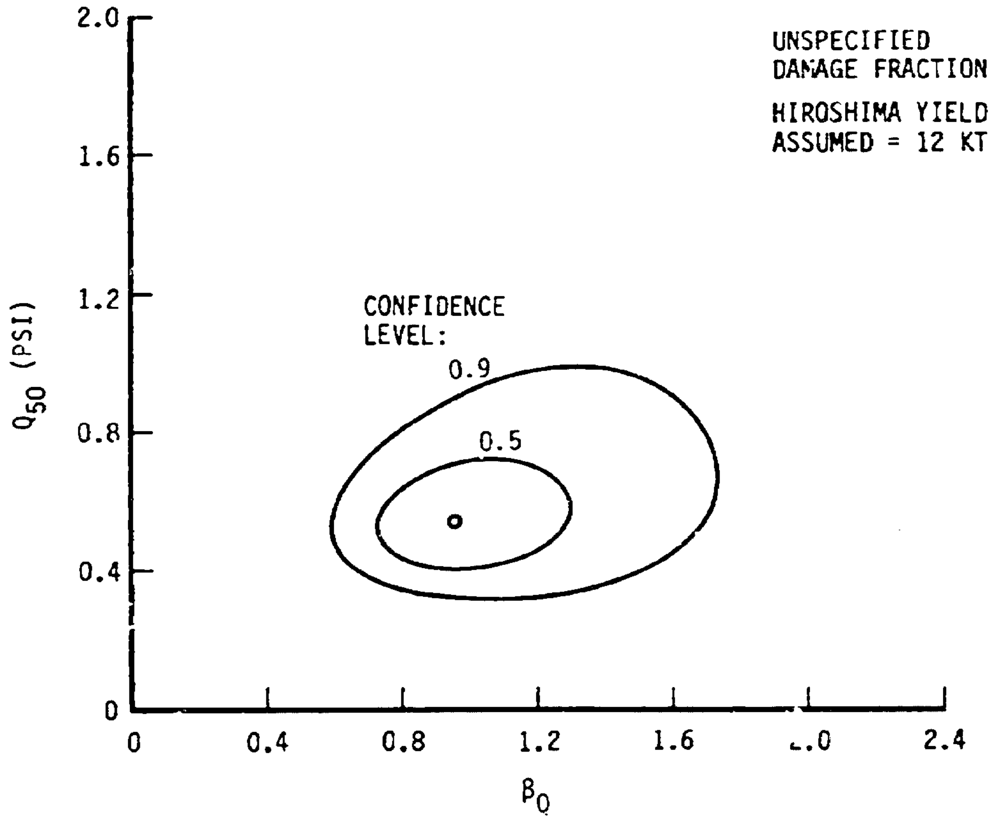


FIGURE 30g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT HIROSHIMA
STEEL ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY
STRUCTURAL DAMAGE TO ROOFS

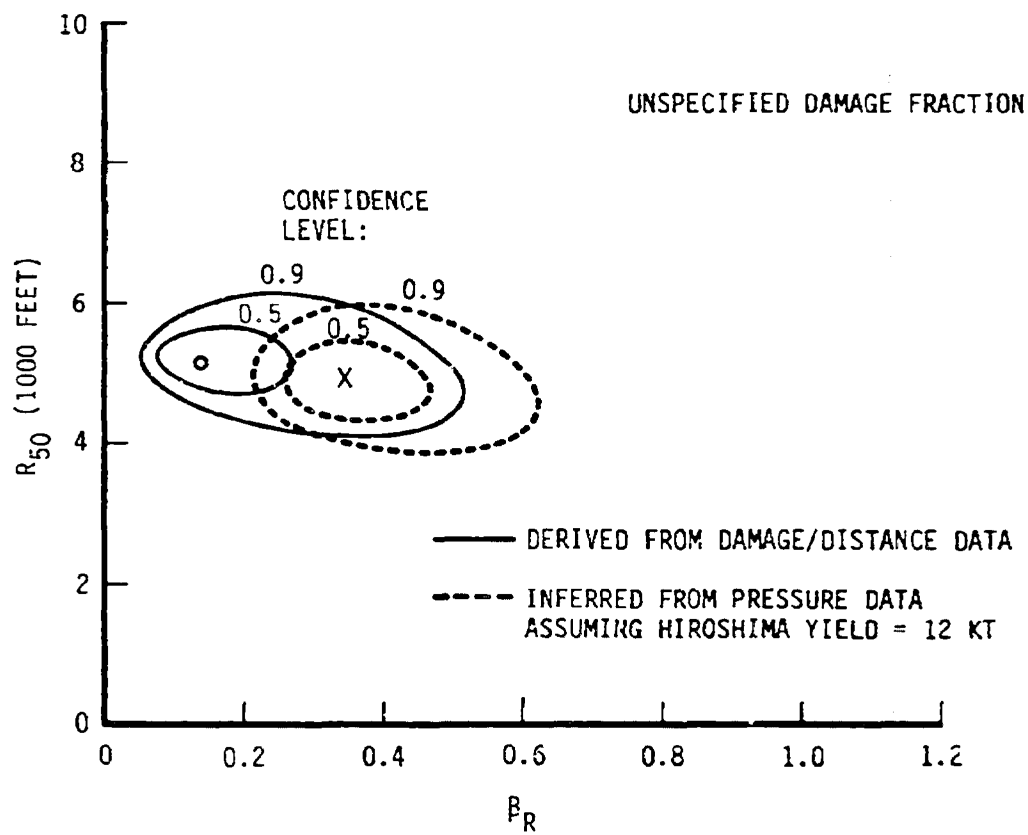
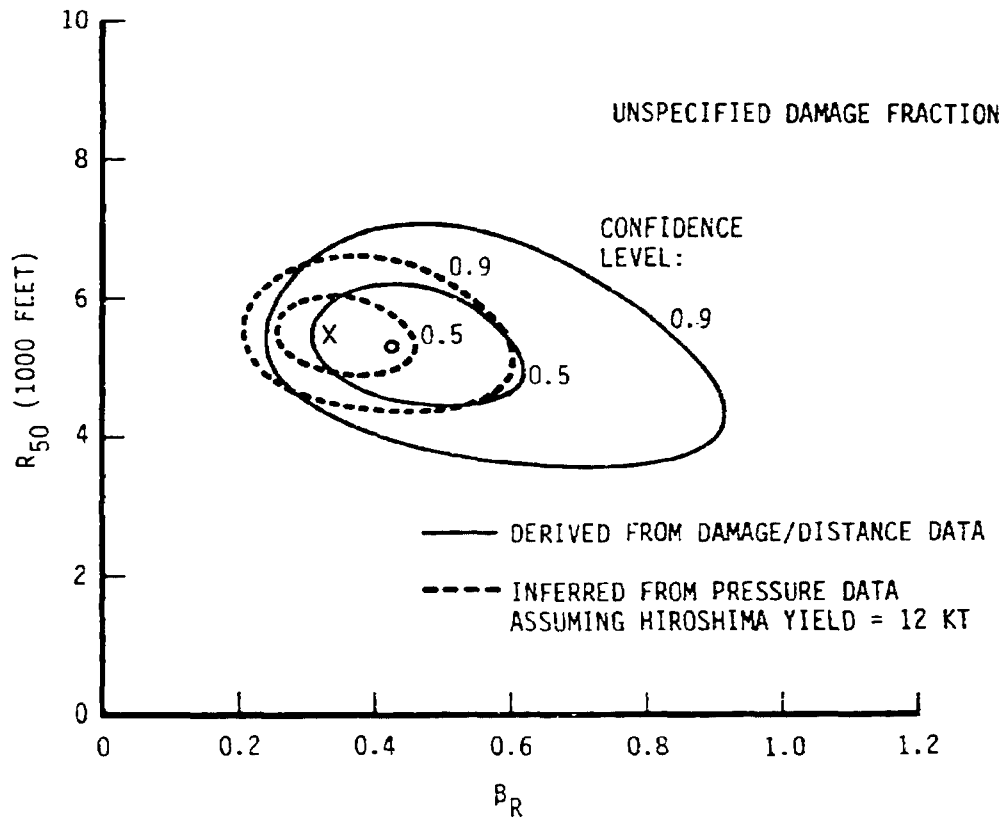


FIGURE 30h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY LIGHT STEEL FRAME BUILDINGS AT NAGASAKI
STEEL ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY
STRUCTURAL DAMAGE TO ROOFS



IV. HEAVY STEEL FRAME BUILDINGS

The data base includes 71 Heavy Steel Frame Buildings, 66 in Nagasaki and only five in Hiroshima. The Single-Story Buildings are divided into two groups, those with cranes less than 25 tons and those with cranes greater than 25 tons. For the Multistory Buildings, the crane size is not distinguished. The breakdown by wall type is as follows:

	SINGLE-STORY			MULTISTORY	
	Light Crane		Heavy Crane		
WALL TYPE	Hiro	Naga	Naga	Hiro	Naga
1	3	23	6	1	23
2	0	9	0	0	4
3	0	0	0	0	0
4	0	0	0	1	1
6	0	0	0	0	0
9	0	0	0	0	0
TOTAL	3	32	6	2	28

Note that the Single-Story Buildings with heavy cranes exist only in Nagasaki, and with only 6 data points no isolation is possible.

The roof types are as follows:

	SINGLE-STORY			MULTISTORY	
	Light Crane		Heavy Crane		
WALL TYPE	Hiro	Naga	Naga	Hiro	Naga
1	0	0	0	2	2
2	0	23	4	0	19
3	1	9	2	0	7
4	0	0	0	0	0
5	2	0	0	0	0
9	0	0	0	0	0
TOTAL	3	32	6	2	28

The Heavy Steel Frame data base is a particularly bad one. All but a few of the buildings are at Nagasaki, and the data sets are characterized by large gaps at certain distances from the ground zero. In general this leads to large confidence regions and unreliable M.L.E.'s. Thus, the results have to be examined carefully.

The summary of the charts is presented on the following page. Note that the Single-Story Buildings data sets include both light and heavy crane types.

Only one of the data sets for the Single-Story Buildings is nearly as good as most of the data sets in the other major classes and that is the Structural Damage criteria. Note that the σ_d of 29 is similar to the other major classes. However, the Structural Damage is probably dominated by the roof damage as the next four sets show. Although the data sets for the Structural Damage to Walls are not very reliable, they give an indication of much greater mean dynamic pressure than for Structural Damage to Roofs.

Unfortunately, the gaps in the data occur in critical places for the Structural Damage to Wall subsets, either driving the β_Q very high with a relatively low mean or very low with a mean pressure of double the other data set. Thus, both normal wall and slow wall subsets probably give unreliable results.

The Structural Damage to Roofs data are also unreliable, especially the slow failing roof subset, which has huge confidence intervals.

For Superficial Damage, the Single-Story and Multistory Buildings were combined to try and obtain more reliable results. A σ_d value of 34 is a bit higher than the other building types, however. The next section combines the light and heavy steel frame for Superficial Damage to obtain a larger data set.

SUMMARY OF HEAVY STEEL FRAME BUILDINGS

TYPE	M.L.E.		MAX. 90% CONF. LIM.		DATA POINTS			
					TOTAL		±1 SIGMA	
	Q_{50} (P_{50})	β_Q (β_P)	Q_{50} (P_{50})	β_Q (β_P)	H	N	H	N
A. SINGLE-STORY								
1. Structural	.47	.84	.17- .82	.32-1.88	3	38	0	15
2. Structural Wall								
a. Normal Wall	.74	1.17	.30-1.40	.54-2.70	3	38	0	20
b. Normal Slow Wall	1.46	.51	.85-2.34	.25-1.55	0	29	0	10
3. Structural Roof								
a. Steel Truss	.48	1.21	.16- .95	.60-2.58	1	38	0	18
b. Steel Truss, Slow	.40	1.44	<.05-1.08	.60->3.00	0	23	0	12
B. ANY STORY								
1. Superficial	(2.35)	.56	1.75-3.25	.36- .88	5	66	0	17

FIGURE 31a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA
STRUCTURAL DAMAGE CRITERIA

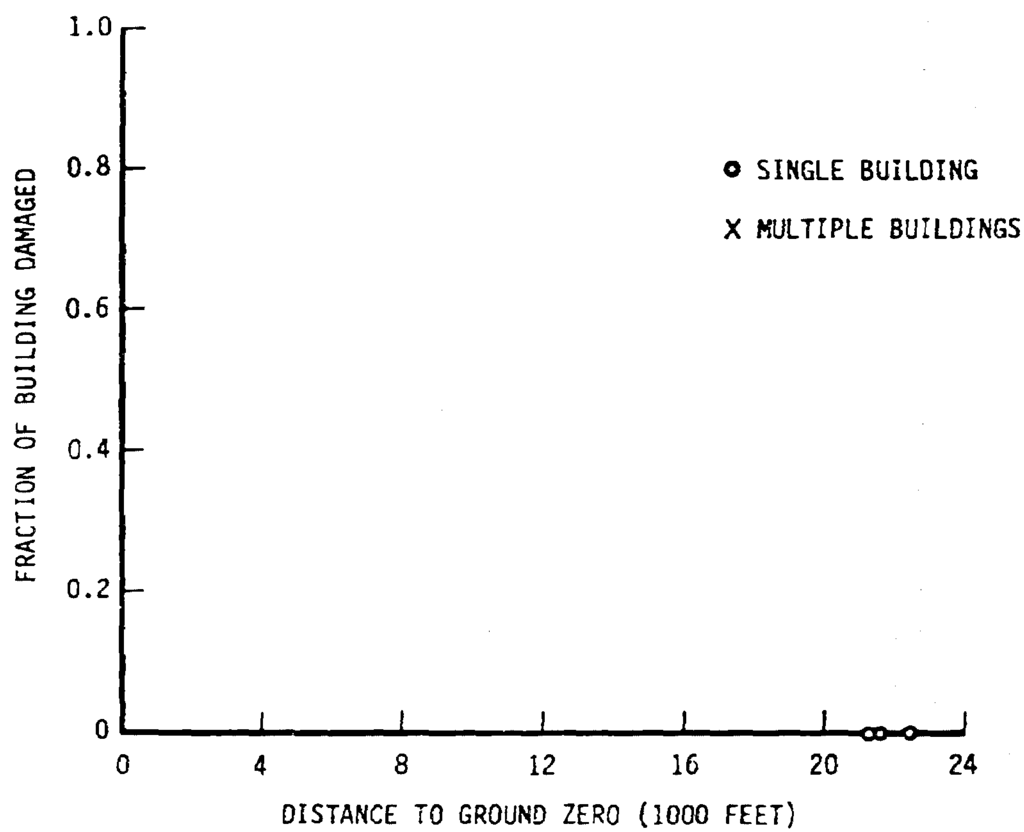


FIGURE 31b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE CRITERIA

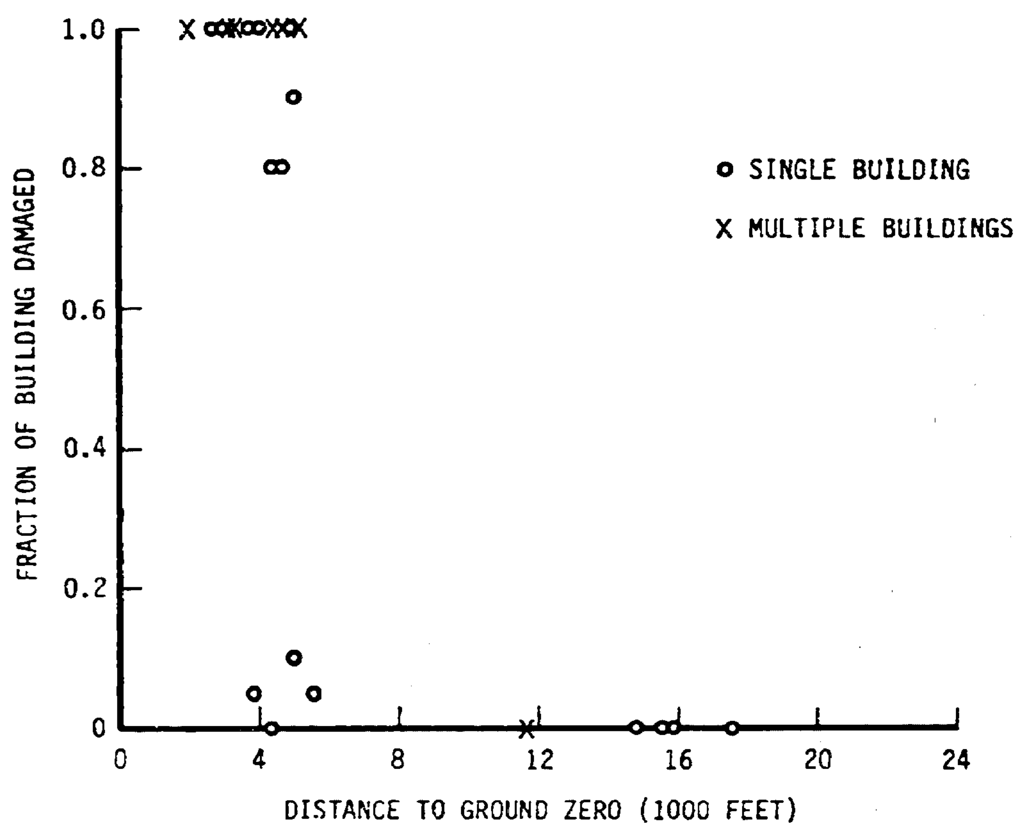


FIGURE 31c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA

STRUCTURAL DAMAGE CRITERIA

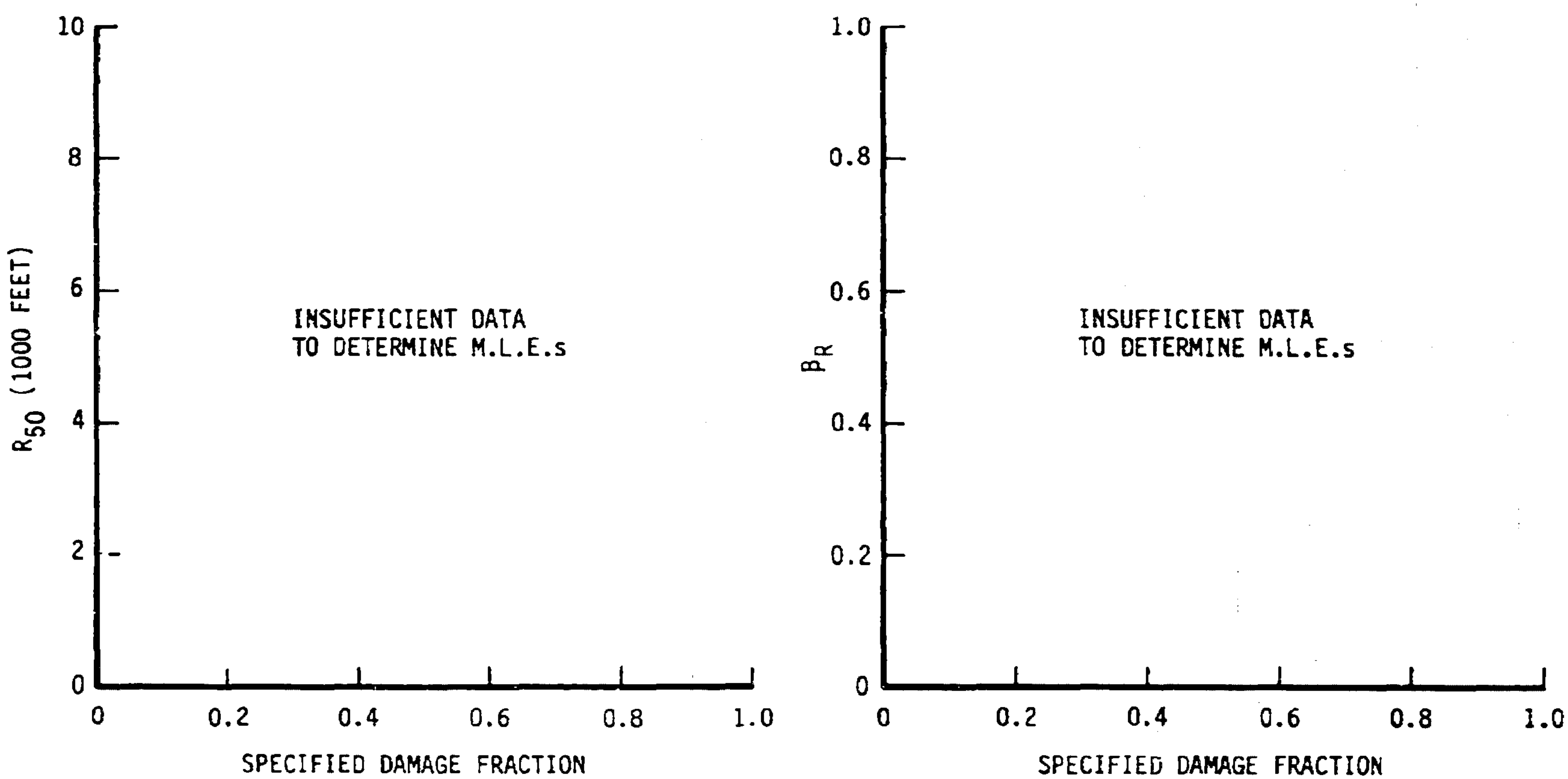
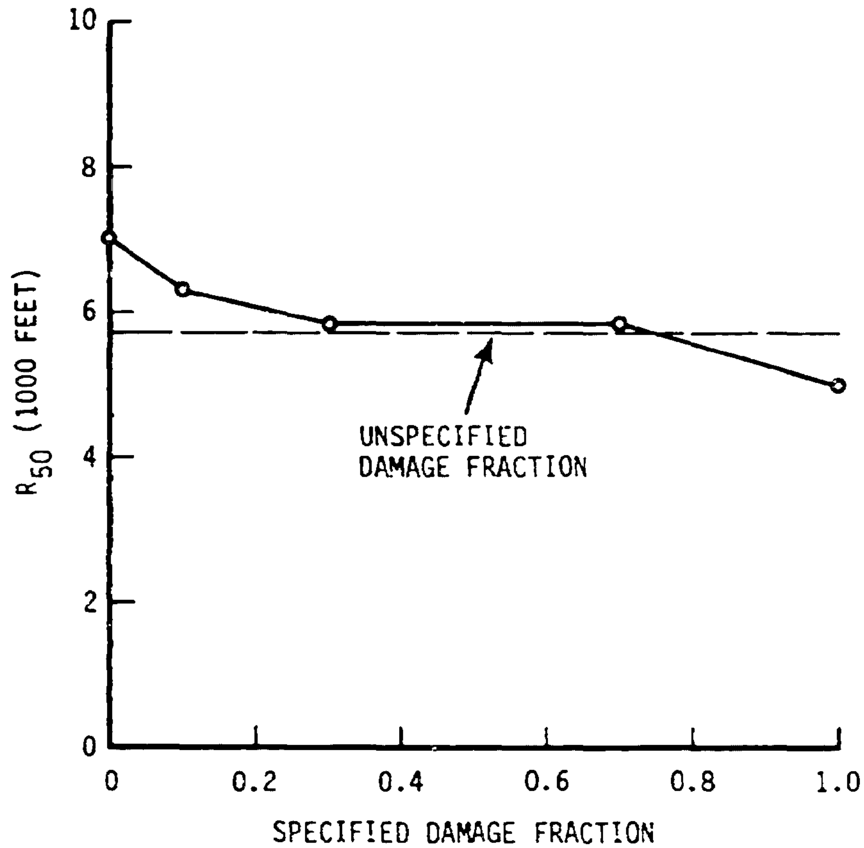


FIGURE 31d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE CRITERIA



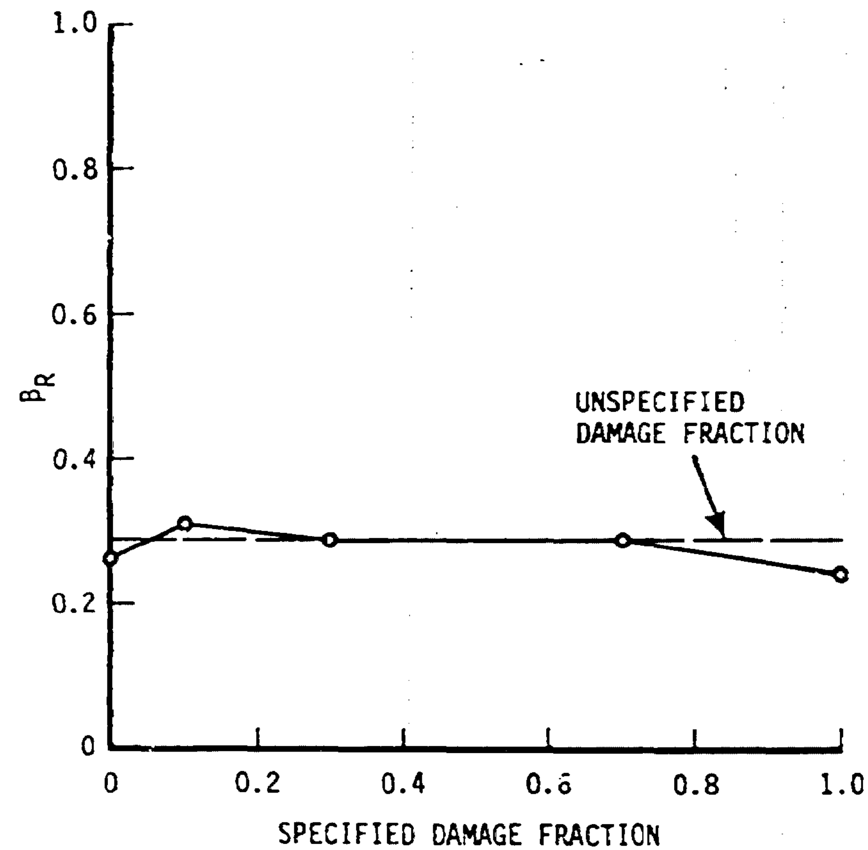
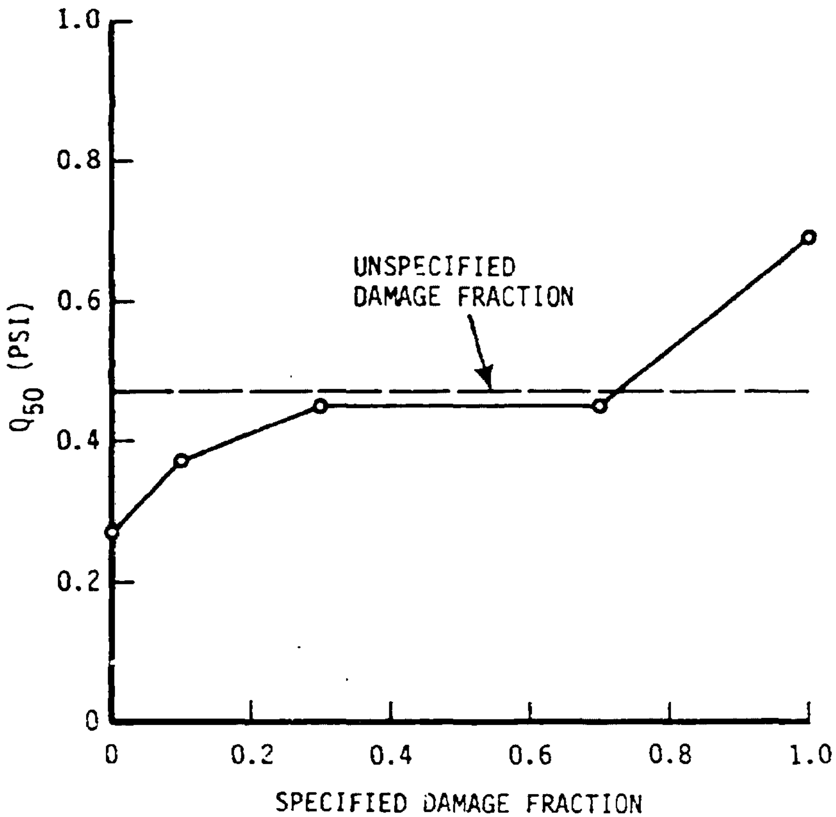


FIGURE 31e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF Q_{50} AND β_Q

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS
STRUCTURAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT



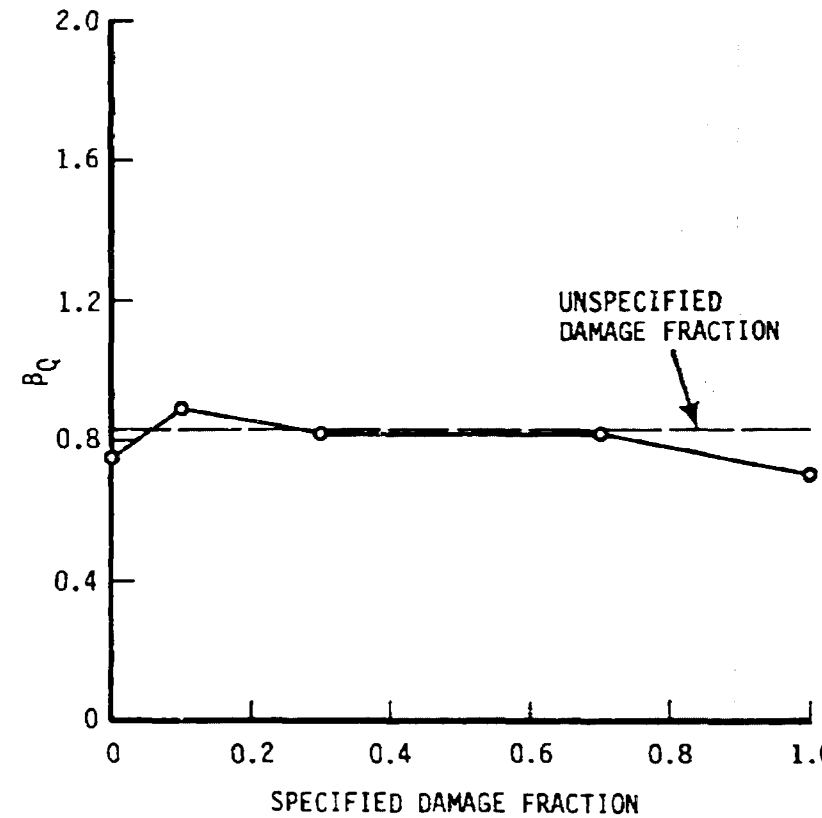


FIGURE 31f

CONFIDENCE REGIONS FOR Q_{50} AND β_Q

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS

STRUCTURAL DAMAGE CRITERIA

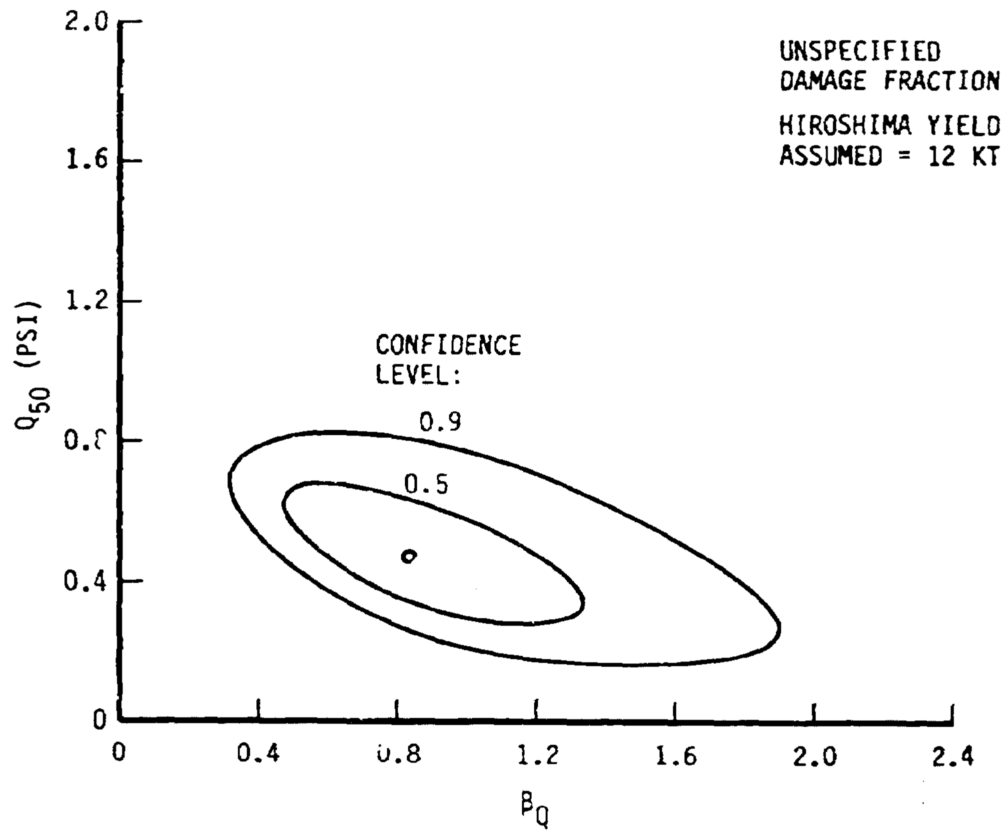


FIGURE 31g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA

STRUCTURAL DAMAGE CRITERIA

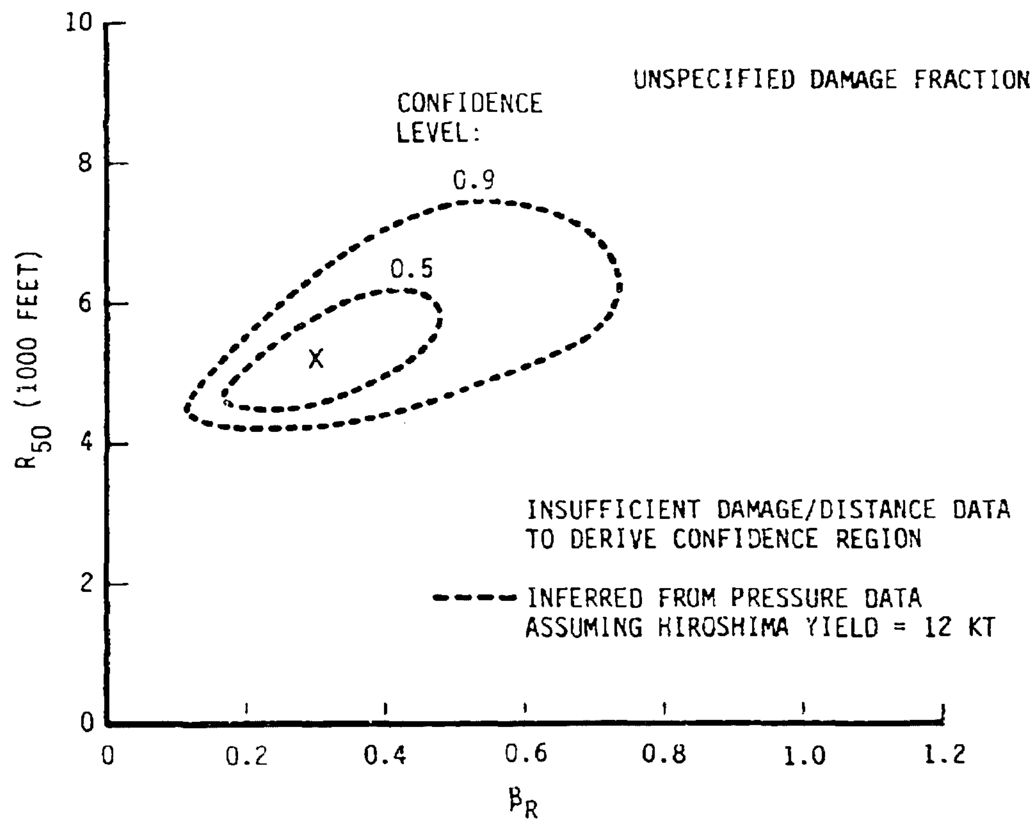


FIGURE 31h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI

STRUCTURAL DAMAGE CRITERIA

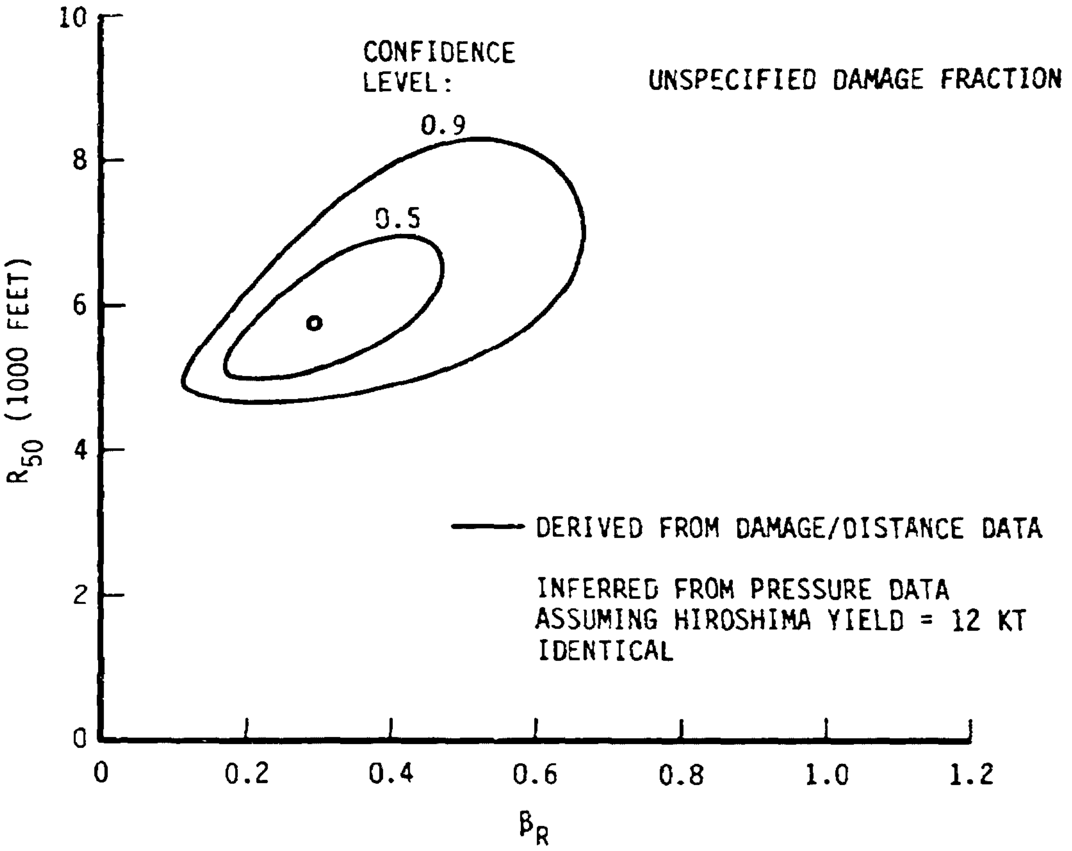


FIGURE 32a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA
I-BEAM OR LATTICE STEEL COLUMNS
STRUCTURAL DAMAGE TO WALLS

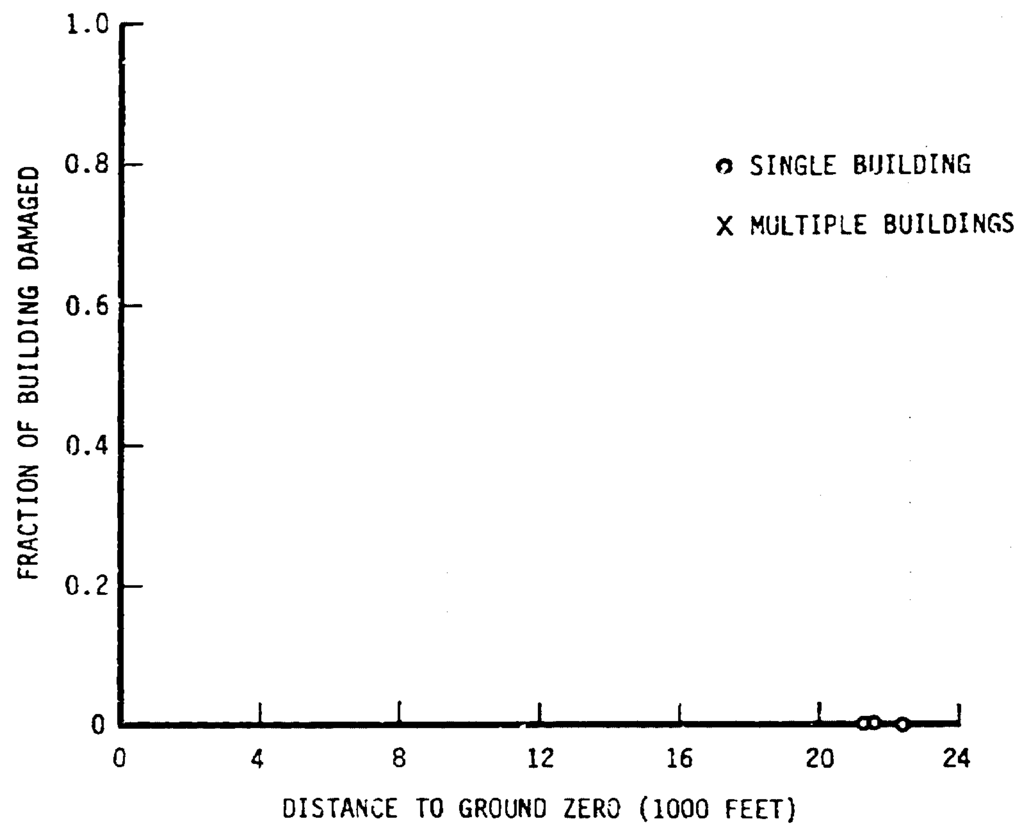


FIGURE 32b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI

I-BEAM OR LATTICE STEEL COLUMNS

STRUCTURAL DAMAGE TO WALLS

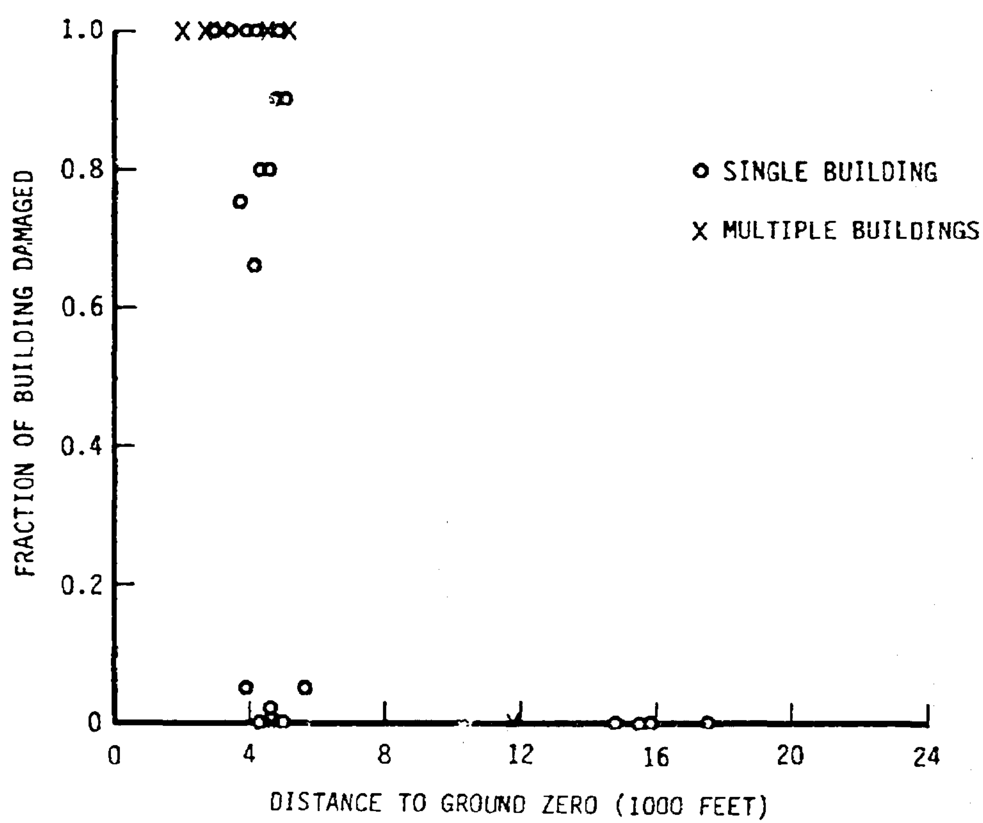


FIGURE 32c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA

I-BEAM OR LATTICE STEEL COLUMNS

STRUCTURAL DAMAGE TO WALLS

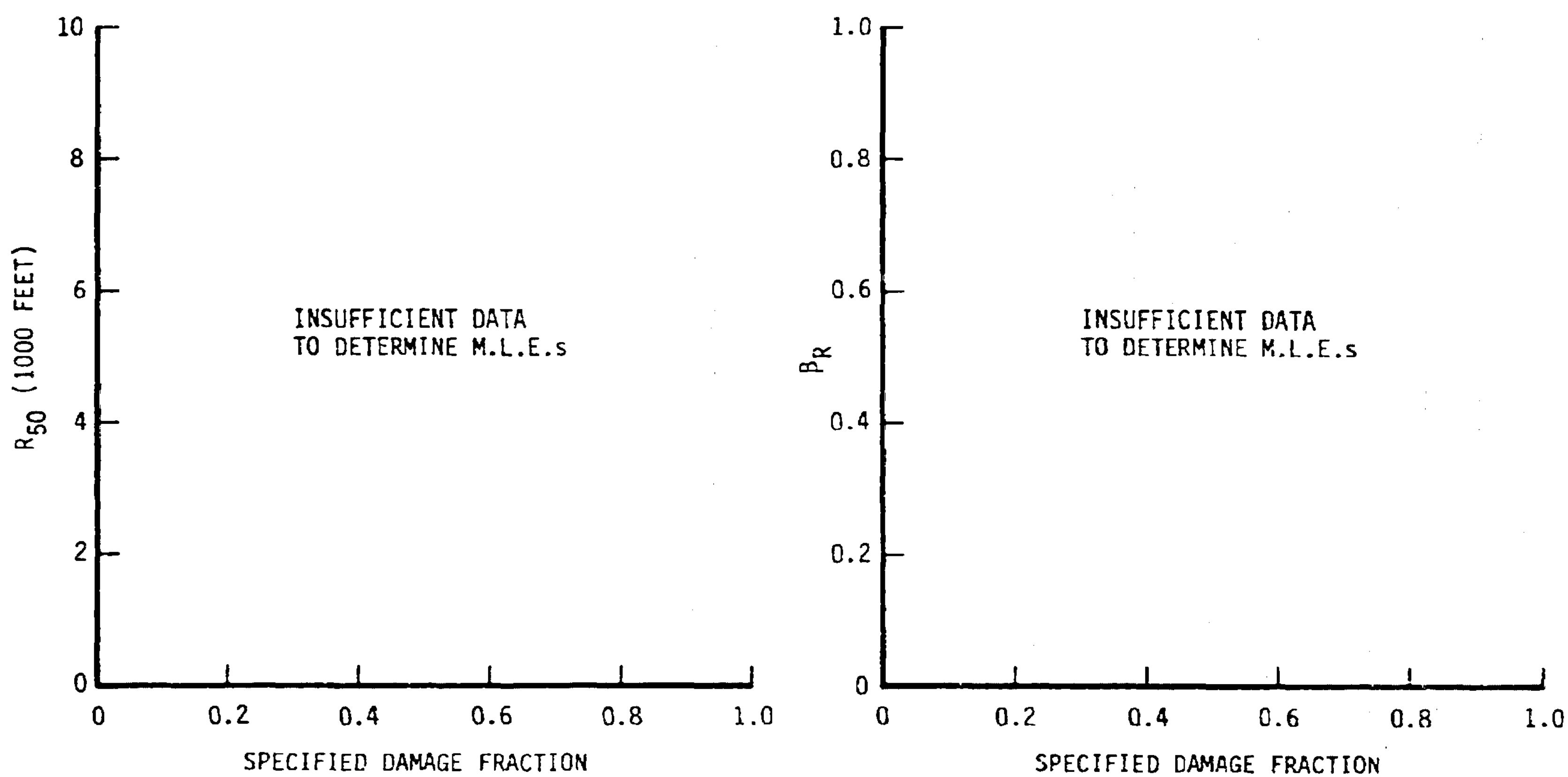


FIGURE 32d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI

I-BEAM OR LATTICE STEEL COLUMNS

STRUCTURAL DAMAGE TO WALLS

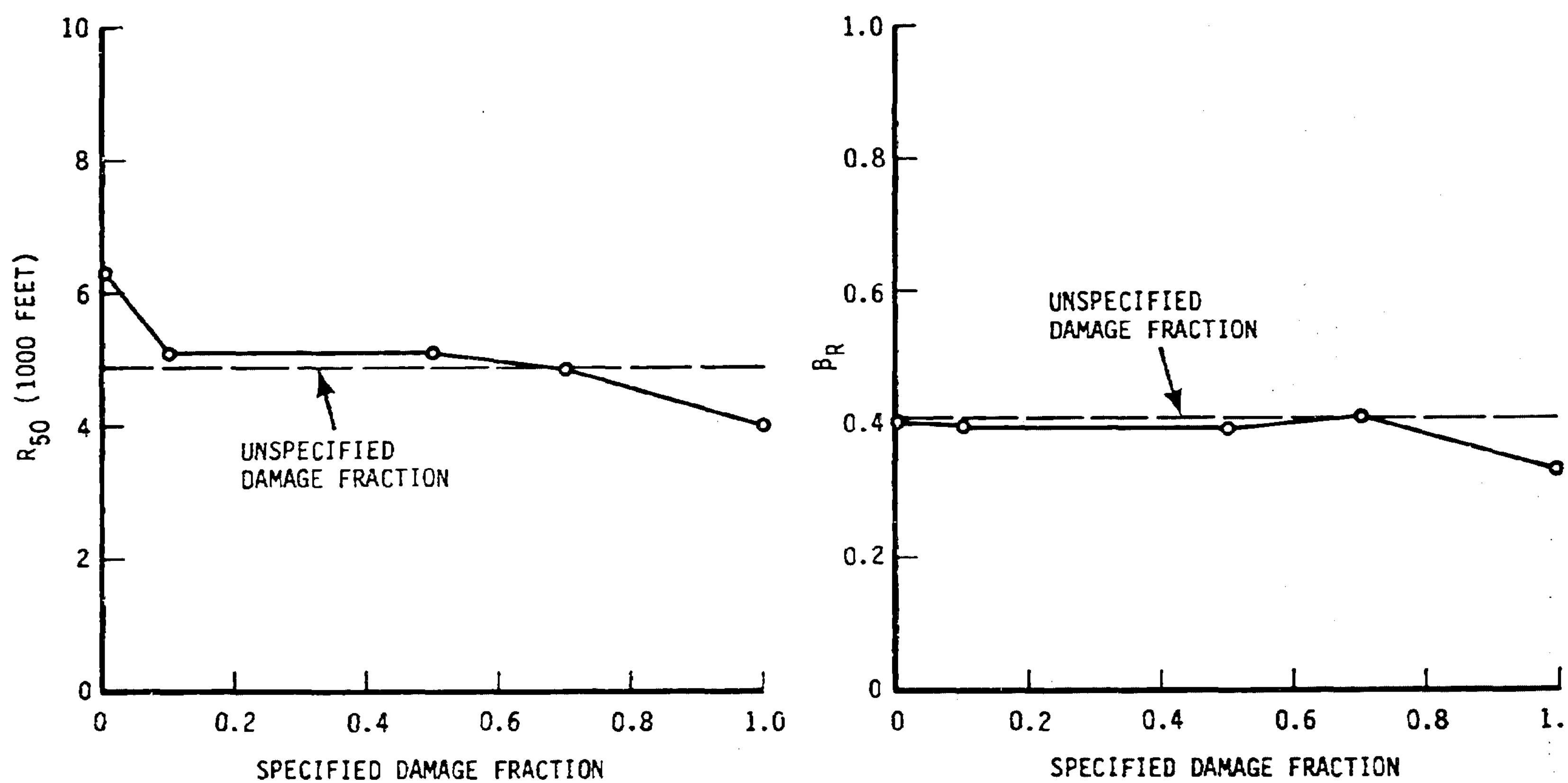


FIGURE 32e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF Q_{50} AND β_Q

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS

I-BEAM OR LATTICE STEEL COLUMNS

STRUCTURAL DAMAGE TO WALLS

HIROSHIMA YIELD ASSUMED = 12 KT

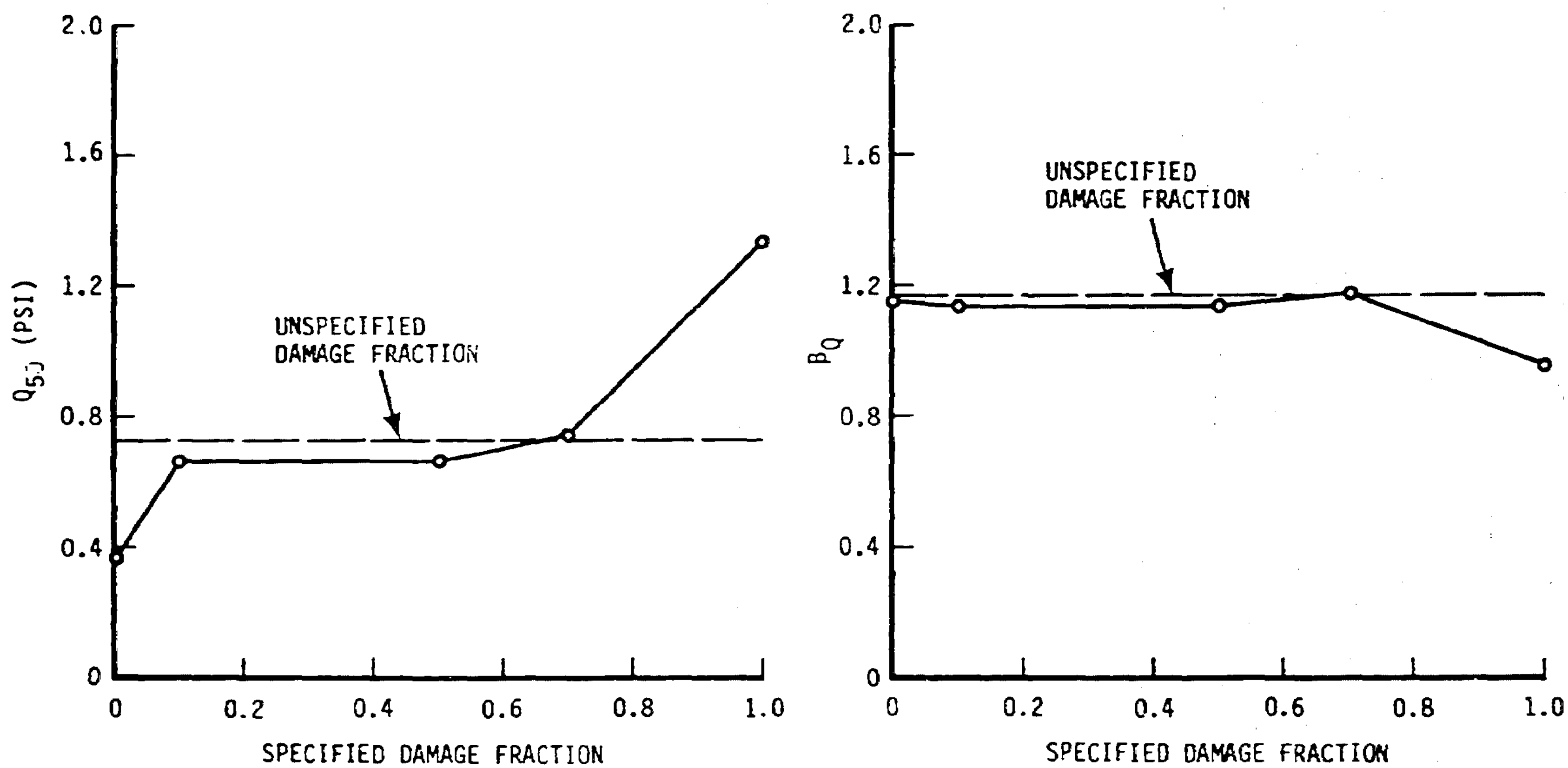


FIGURE 32f

CONFIDENCE REGIONS FOR Q_{50} AND β_Q

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS

I-BEAM OR LATTICE STEEL COLUMNS

STRUCTURAL DAMAGE TO WALLS

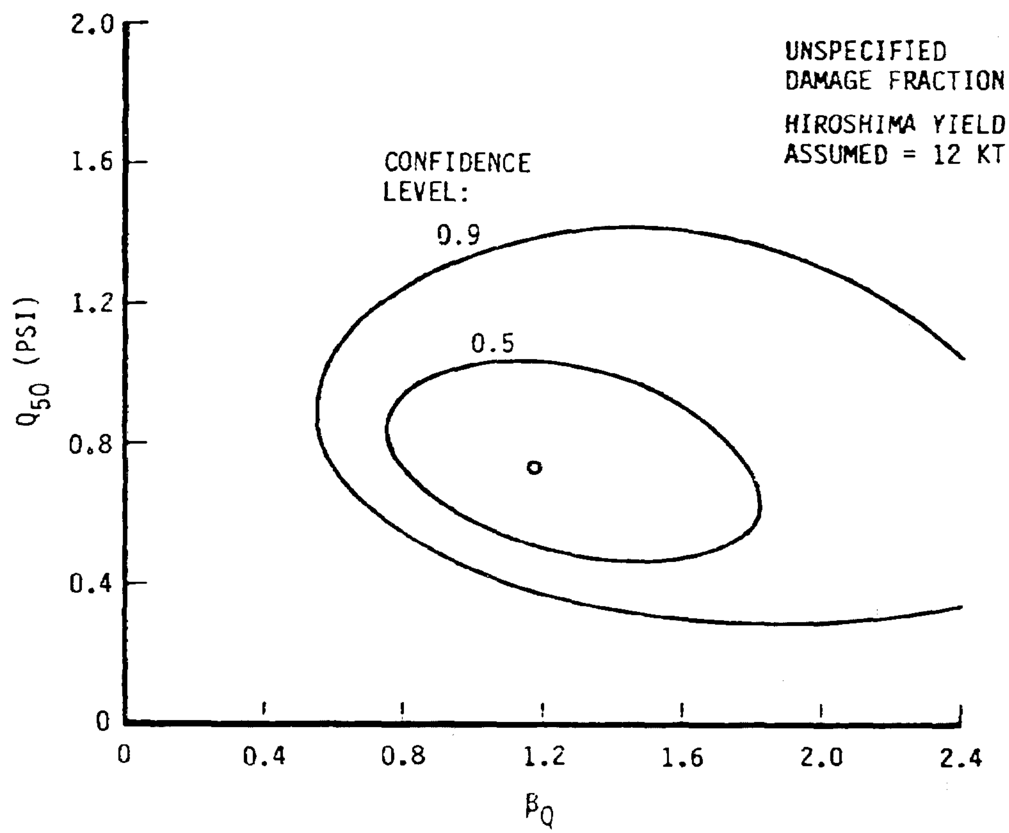


FIGURE 32g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA

I-BEAM OR LATTICE STEEL COLUMNS

STRUCTURAL DAMAGE TO WALLS

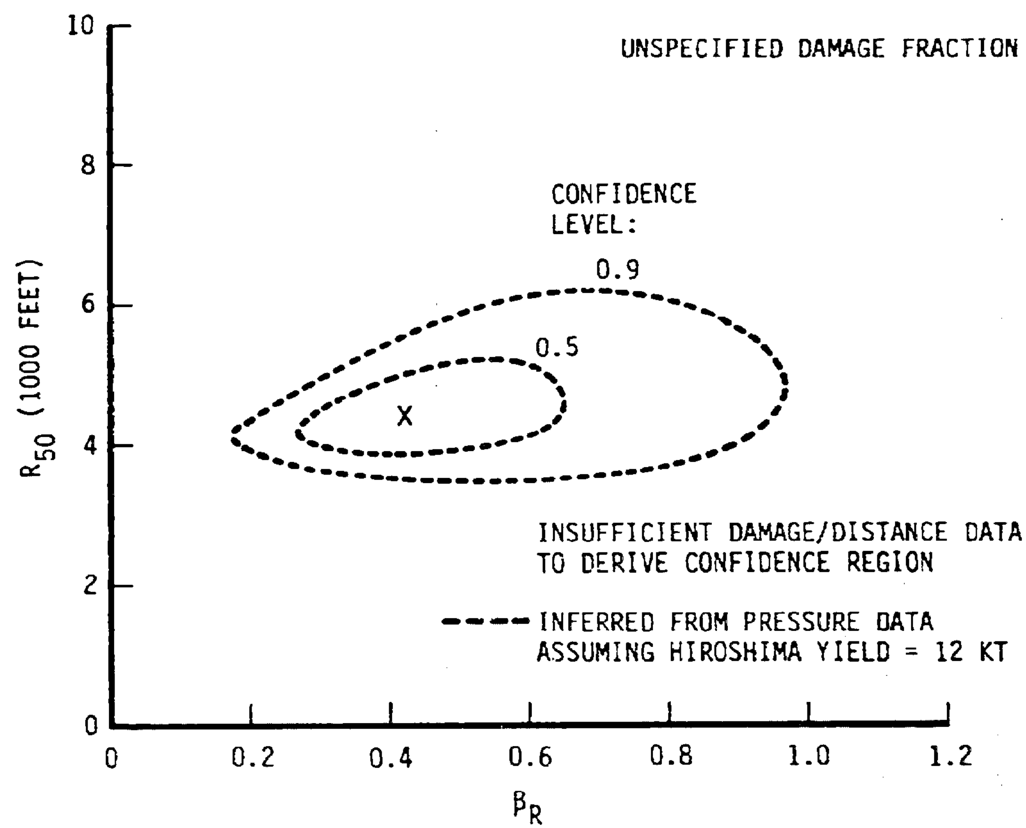


FIGURE 32h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI

I-BEAM OR LATTICE STEEL COLUMNS

STRUCTURAL DAMAGE TO WALLS

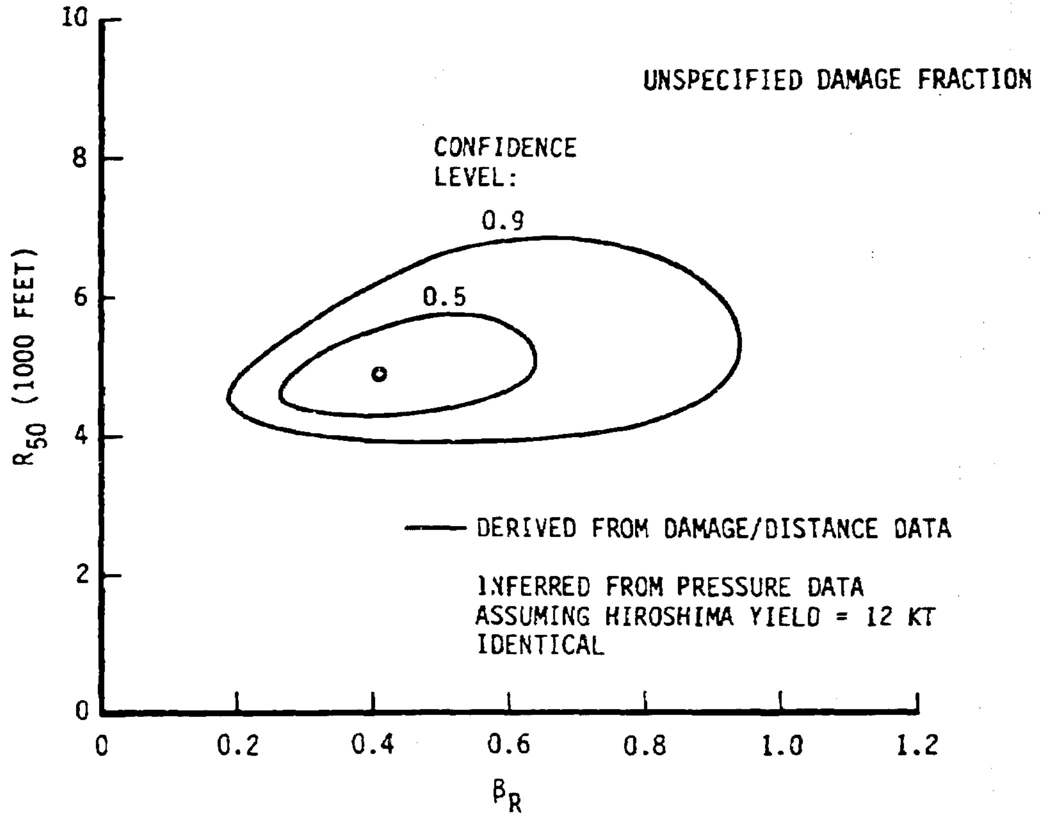


FIGURE 33a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA

WALL COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO WALLS

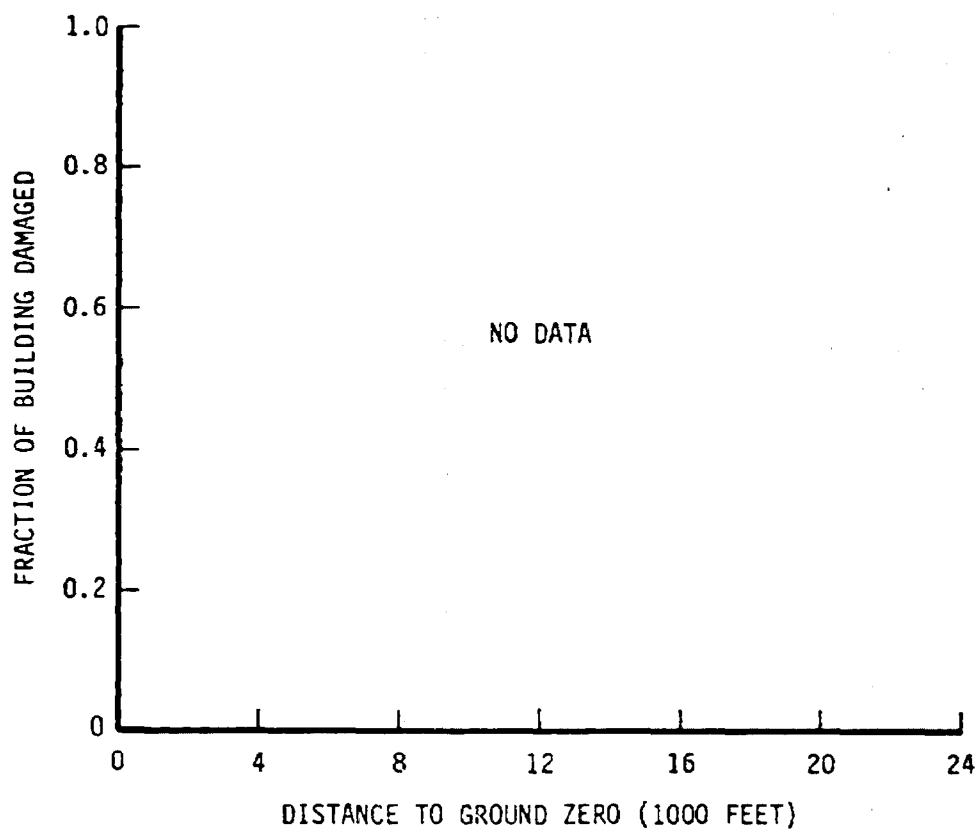


FIGURE 33b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI
WALL COVER MATERIAL FAILS SLOWLY
STRUCTURAL DAMAGE TO WALLS

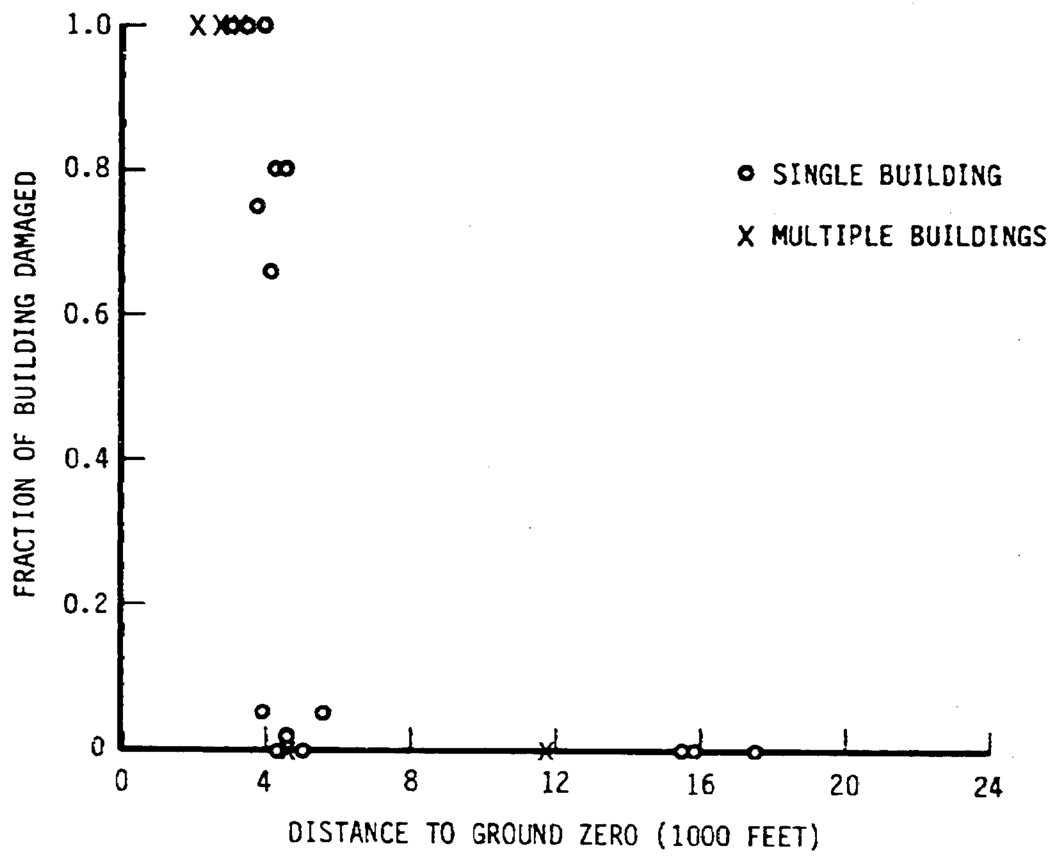


FIGURE 33c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA

WALL COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO WALLS

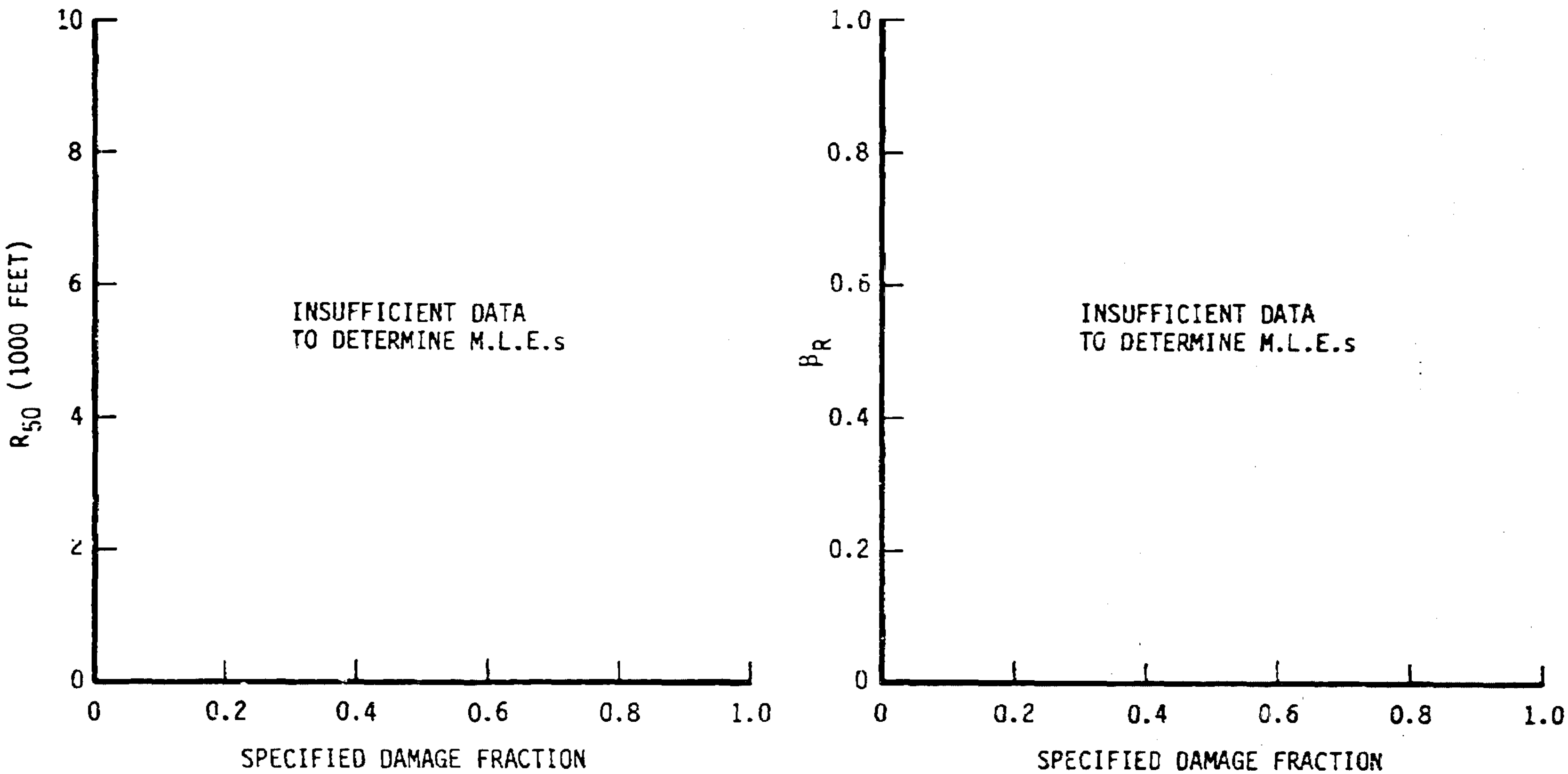


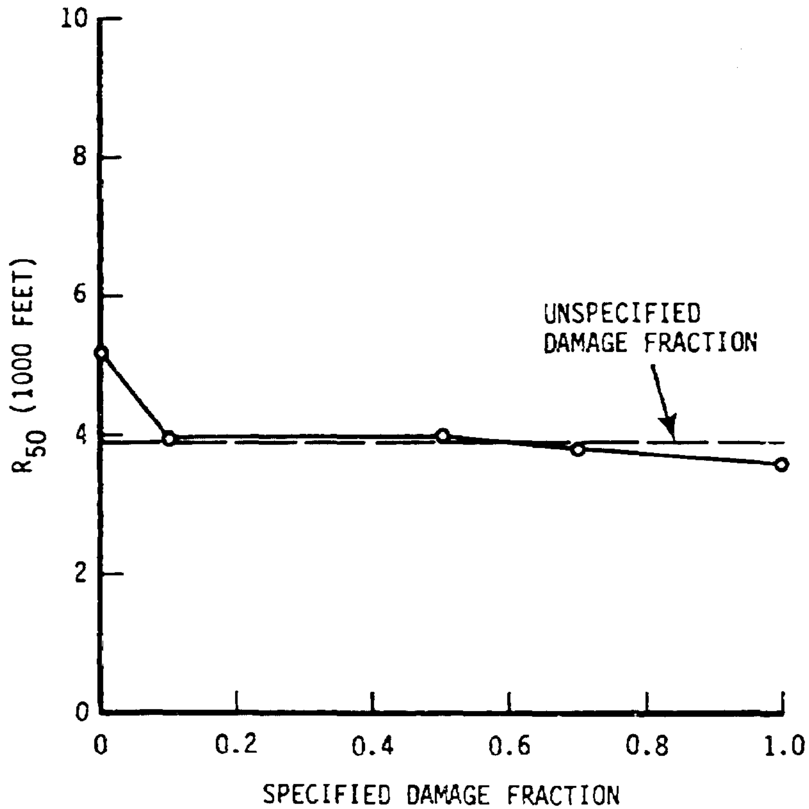
FIGURE 33d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI

WALL COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO WALLS



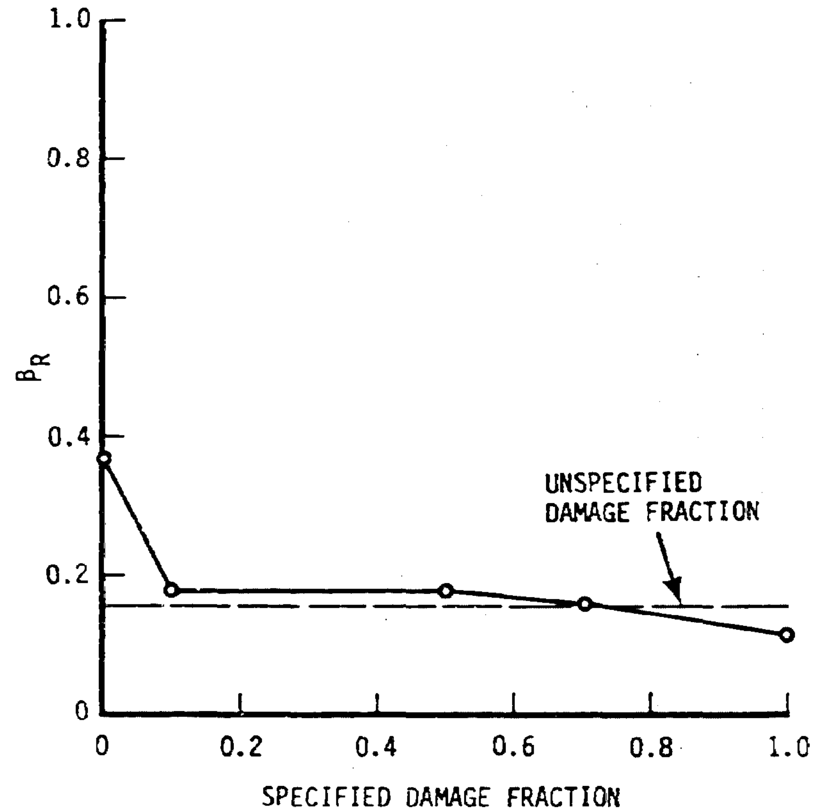


FIGURE 33e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF Q_{50} AND β_Q

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS

WALL COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO WALLS

HIROSHIMA YIELD ASSUMED = 12 KT

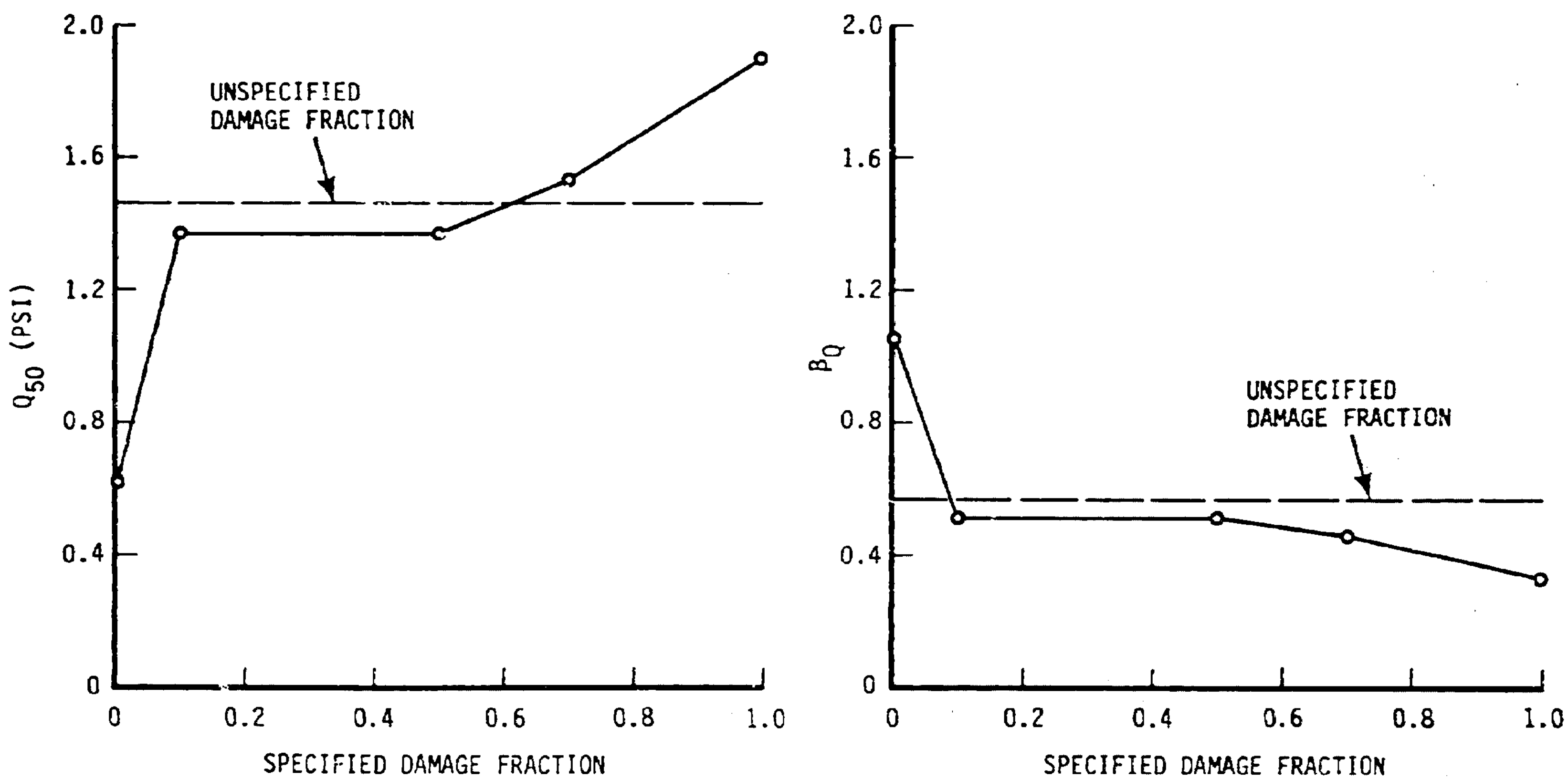


FIGURE 33f

CONFIDENCE REGIONS FOR Q_{50} AND β_Q

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS

WALL COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO WALLS

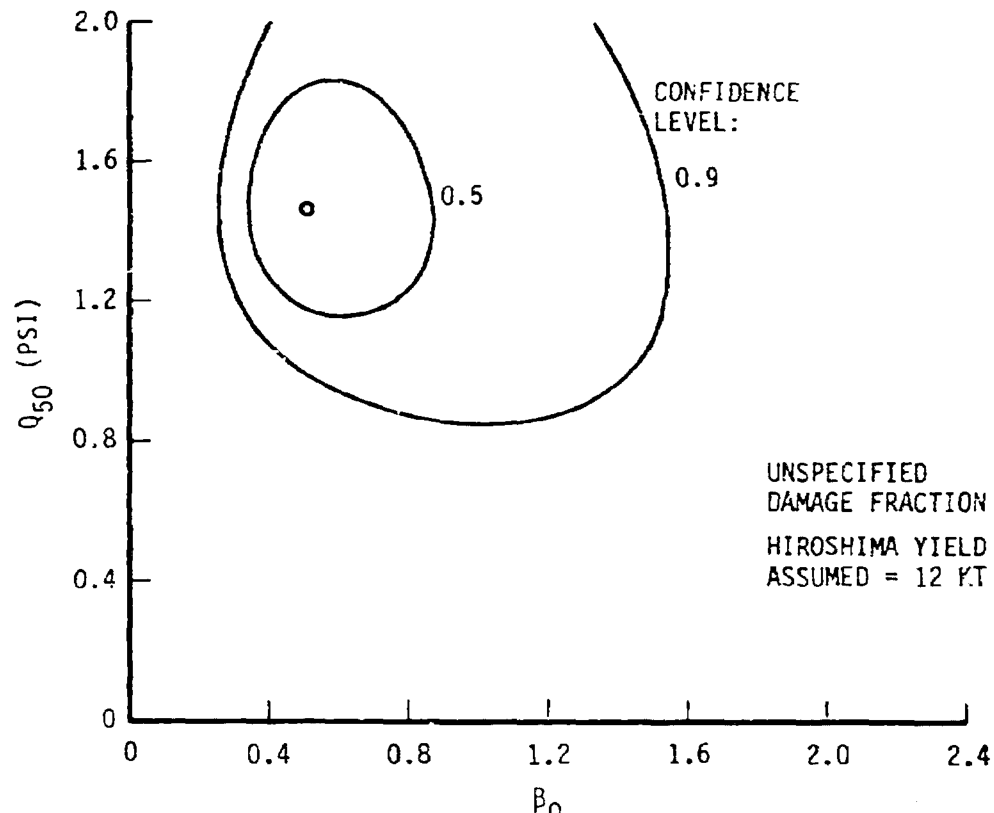


FIGURE 33g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA

WALL COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO WALLS

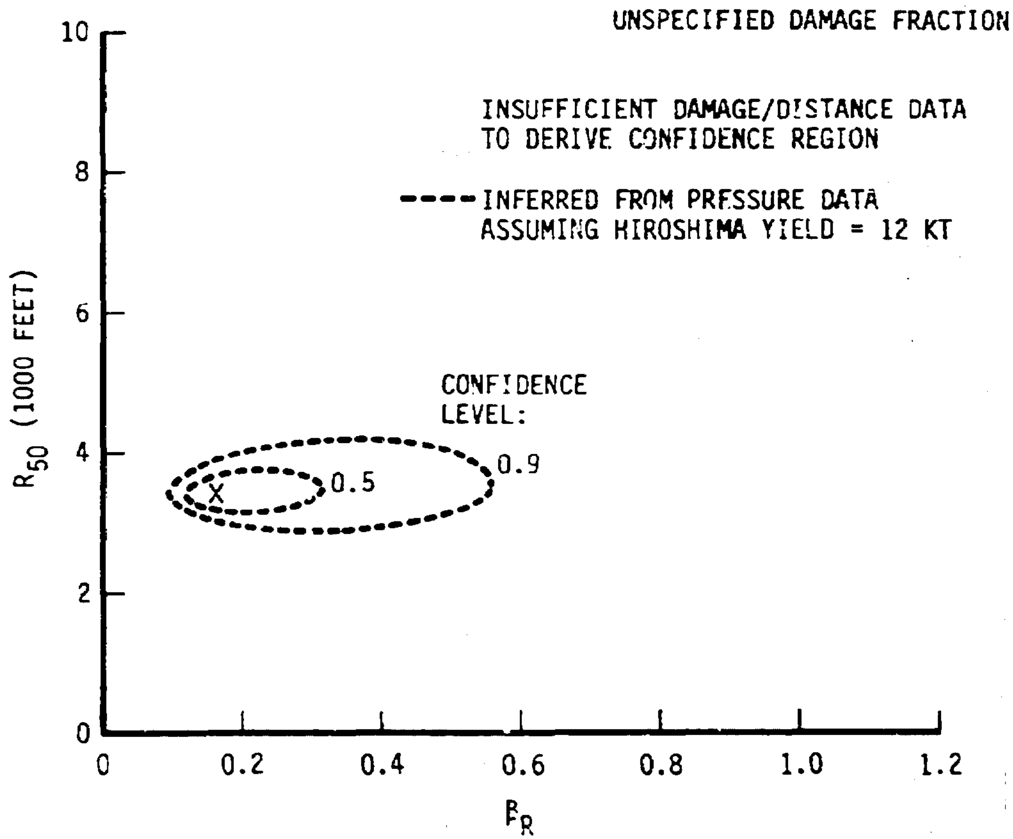


FIGURE 33h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI

WALL COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO WALLS

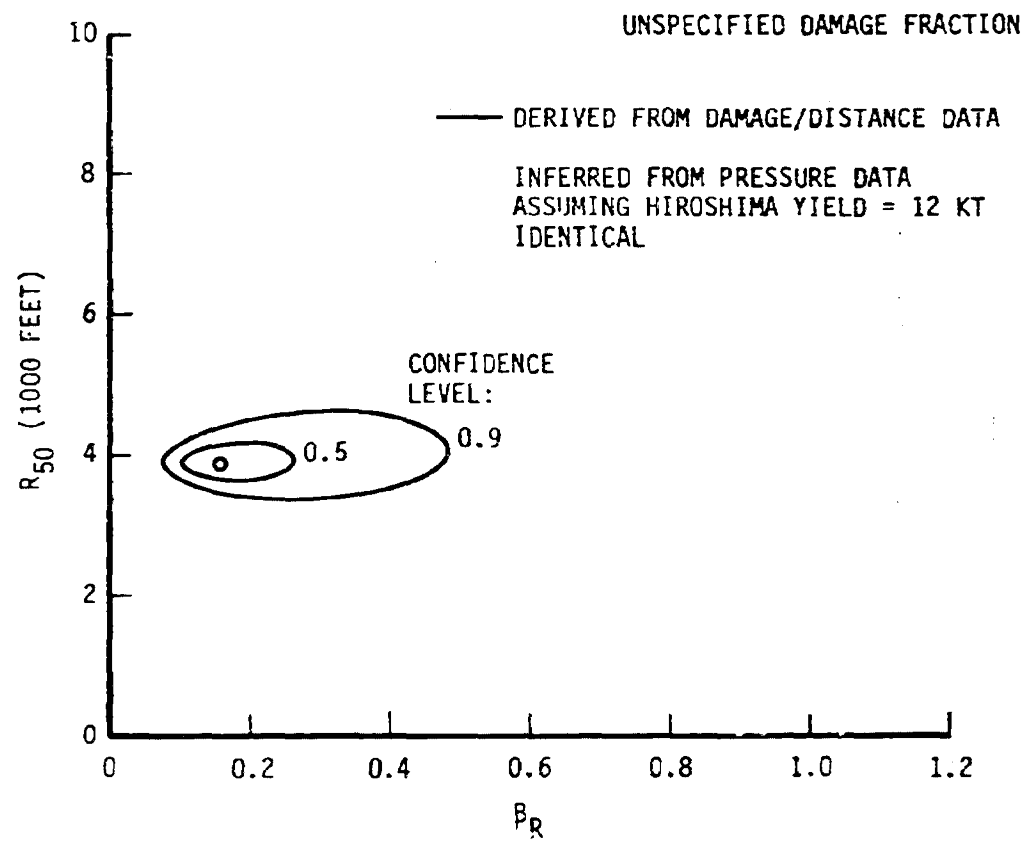


FIGURE 34a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA
STEEL ROOF TRUSSES
STRUCTURAL DAMAGE TO ROOFS

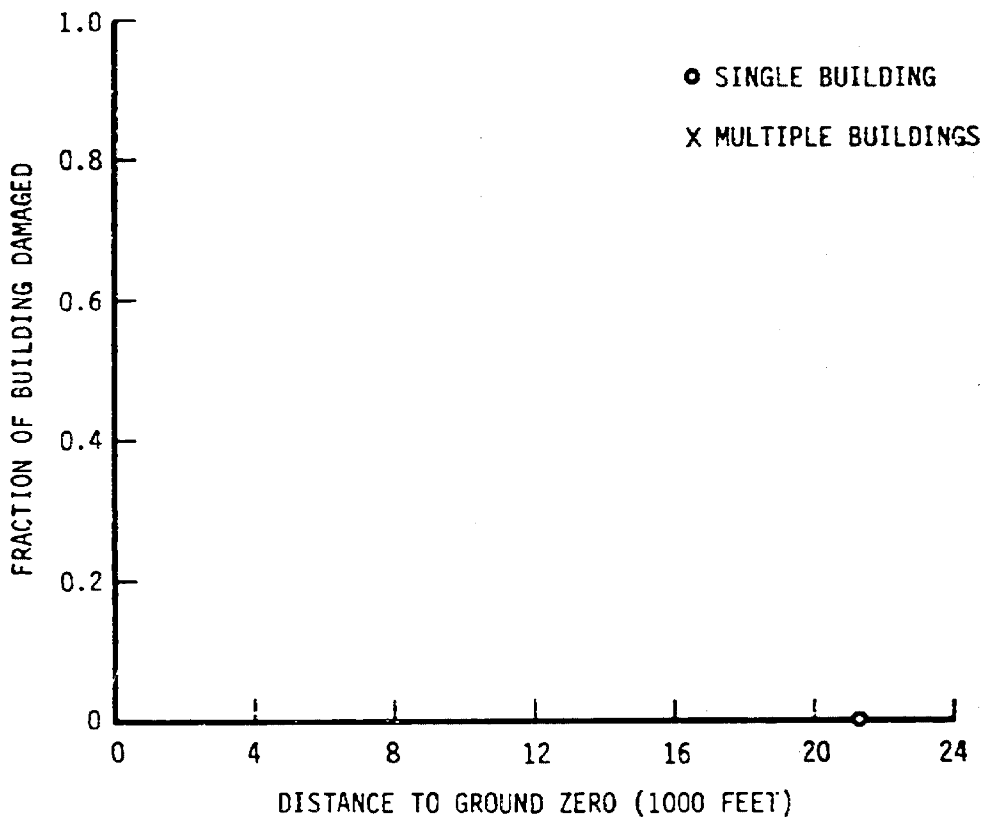


FIGURE 34b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI

STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

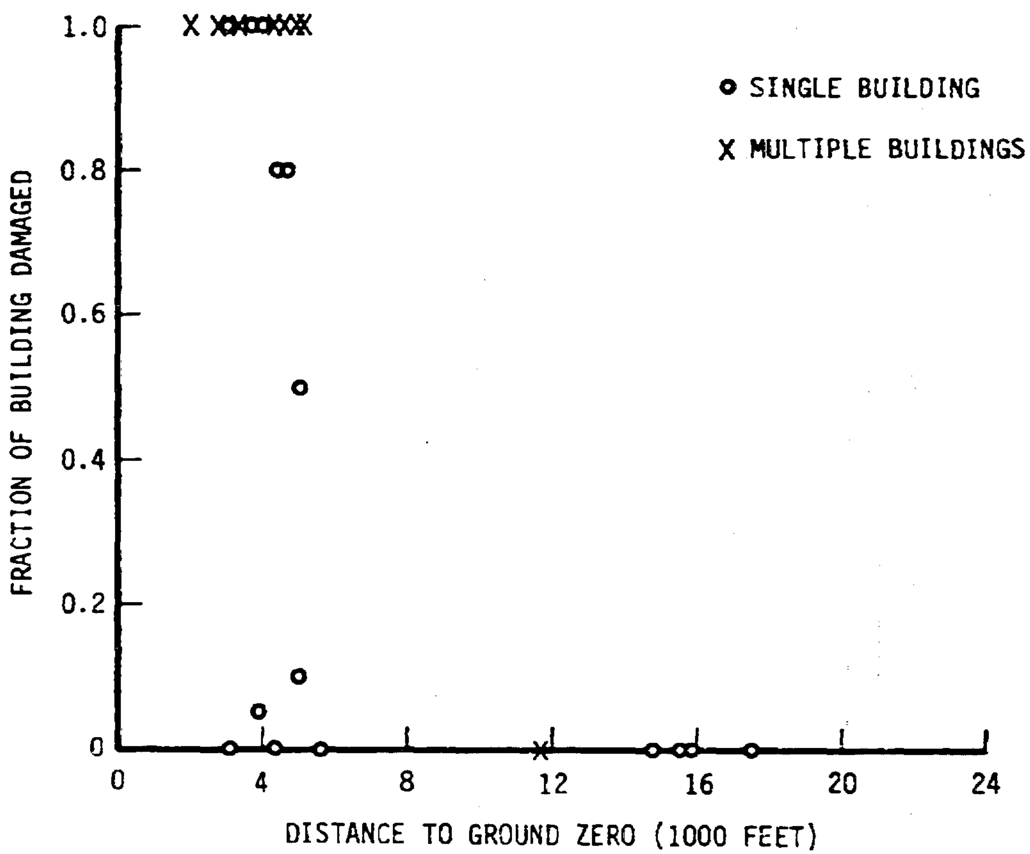


FIGURE 34c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA

STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

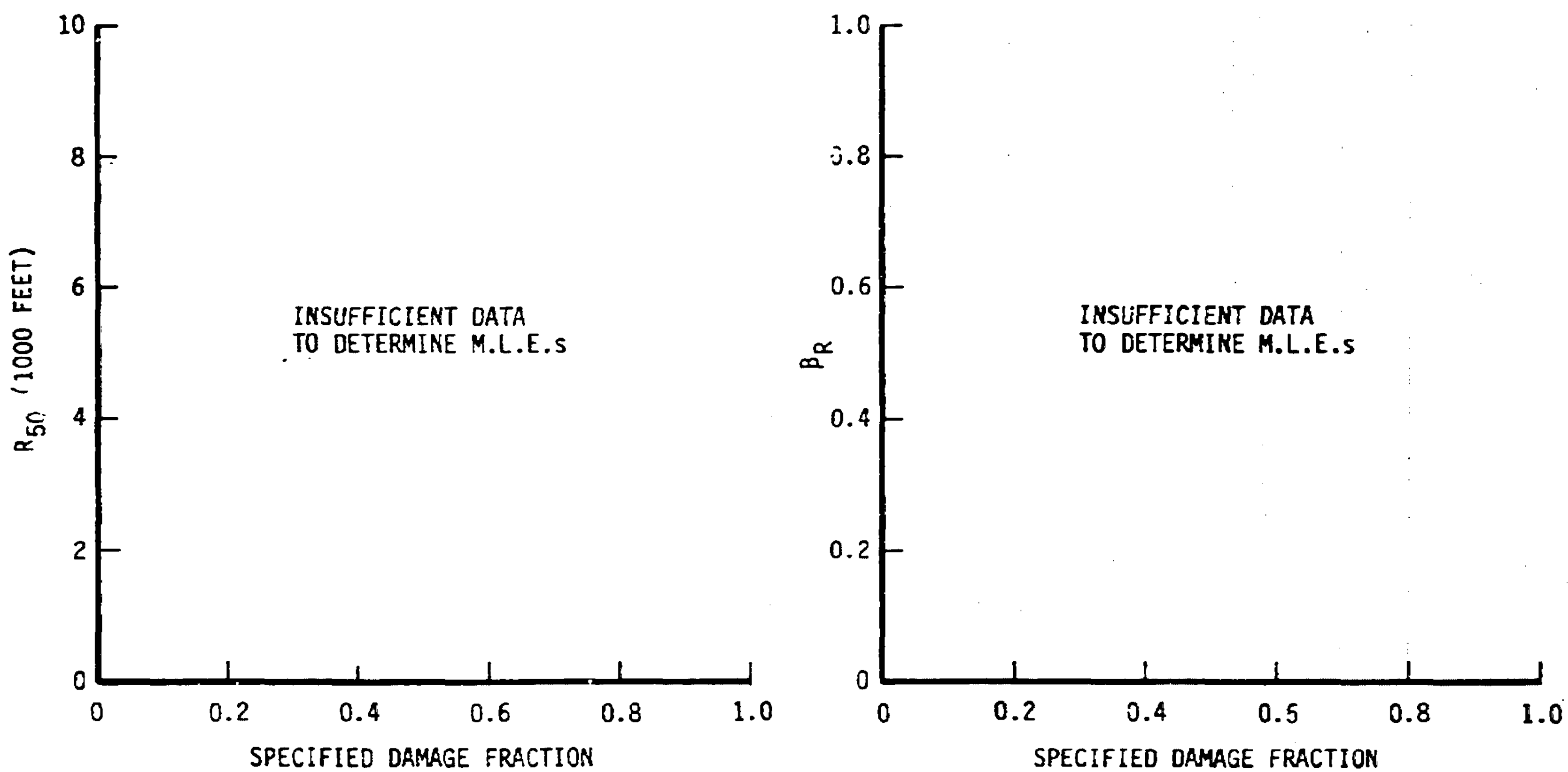


FIGURE 34d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI

STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

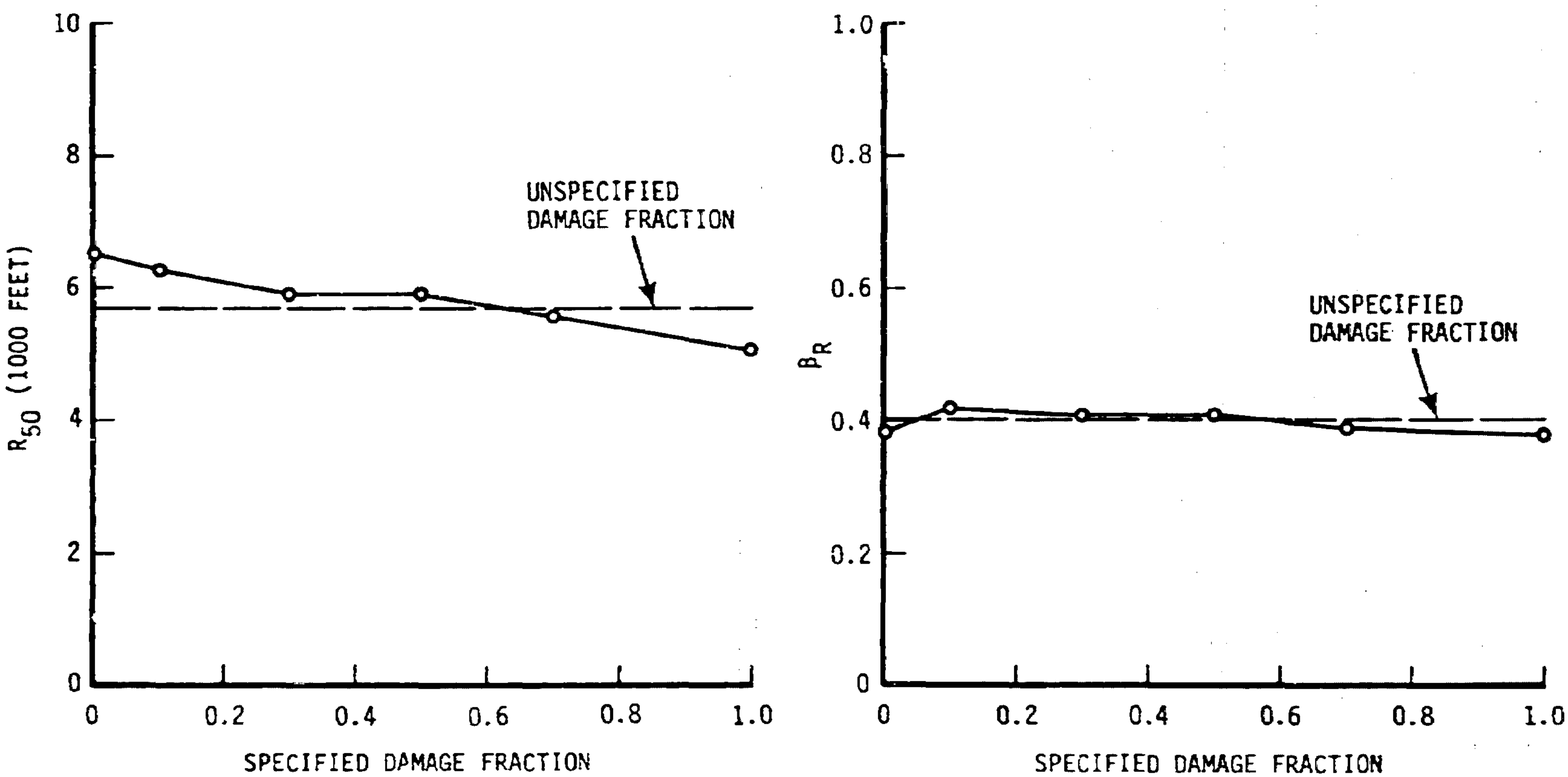


FIGURE 34e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF Q_{50} AND β_Q

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS

STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

HIROSHIMA YIELD ASSUMED = 12 KT

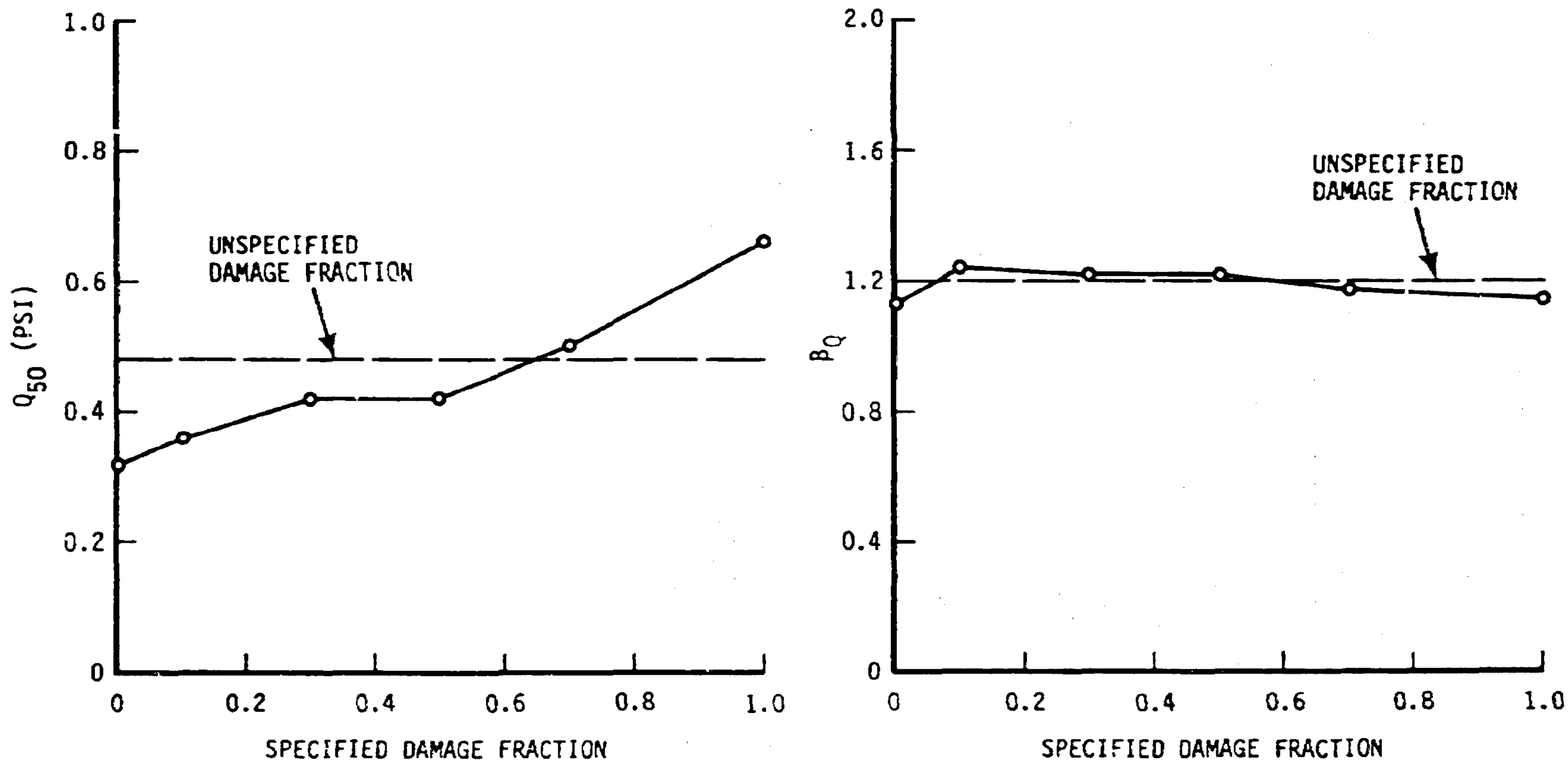


FIGURE 34f

CONFIDENCE REGIONS FOR Q_{50} AND β_Q

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS

STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

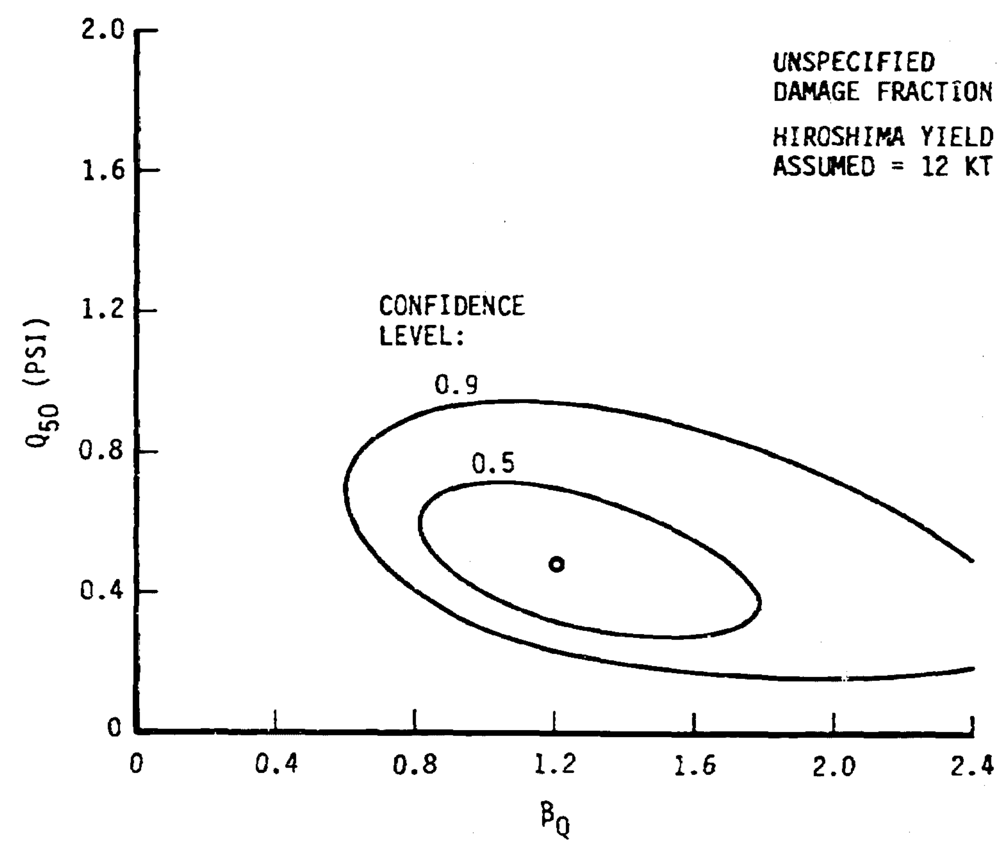


FIGURE 34g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA

STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

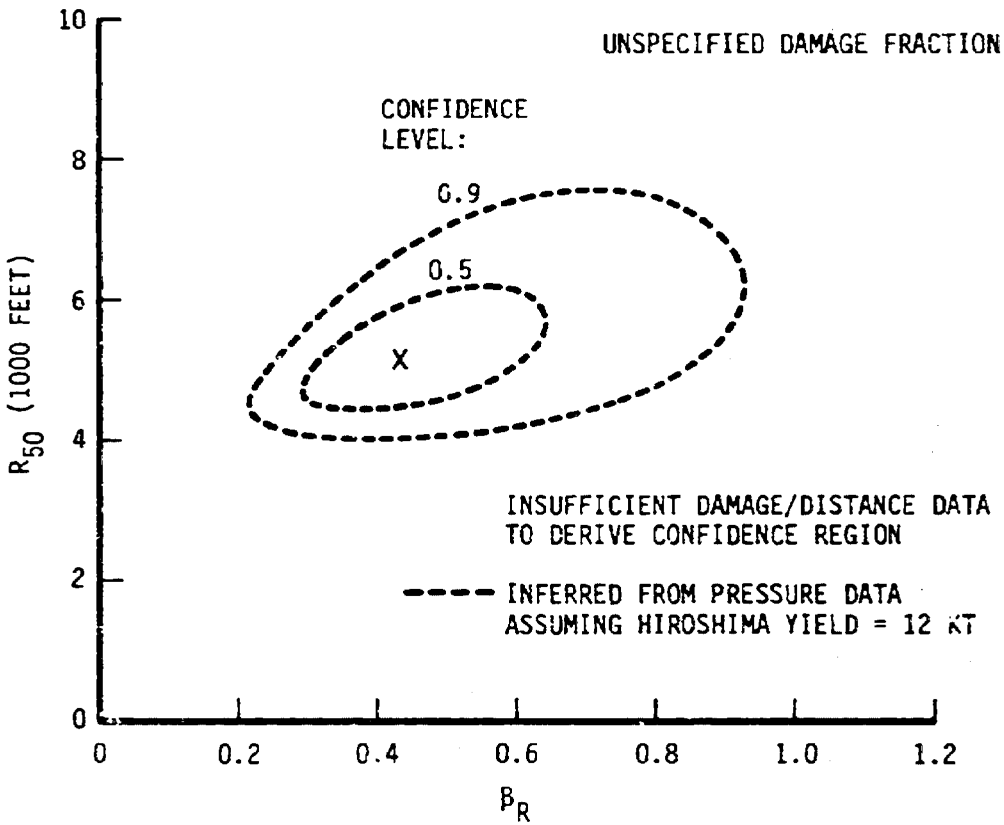


FIGURE 34h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI

STEEL ROOF TRUSSES

STRUCTURAL DAMAGE TO ROOFS

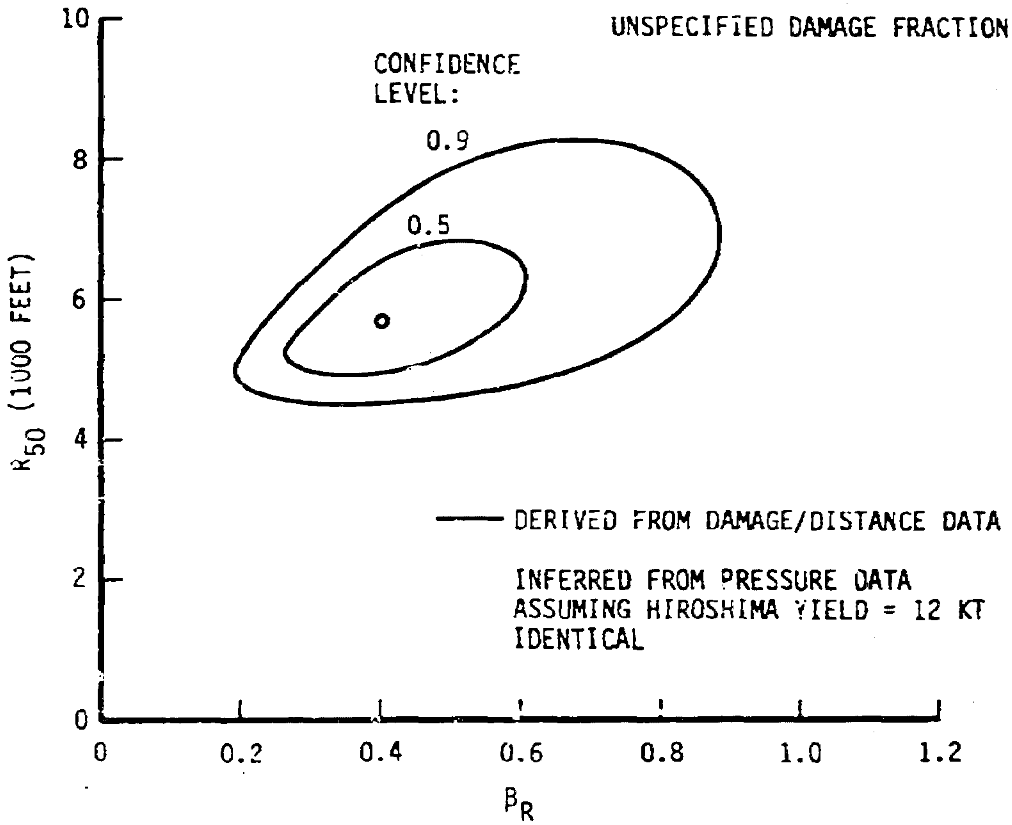


FIGURE 35a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA
STEEL ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY
STRUCTURAL DAMAGE TO ROOFS

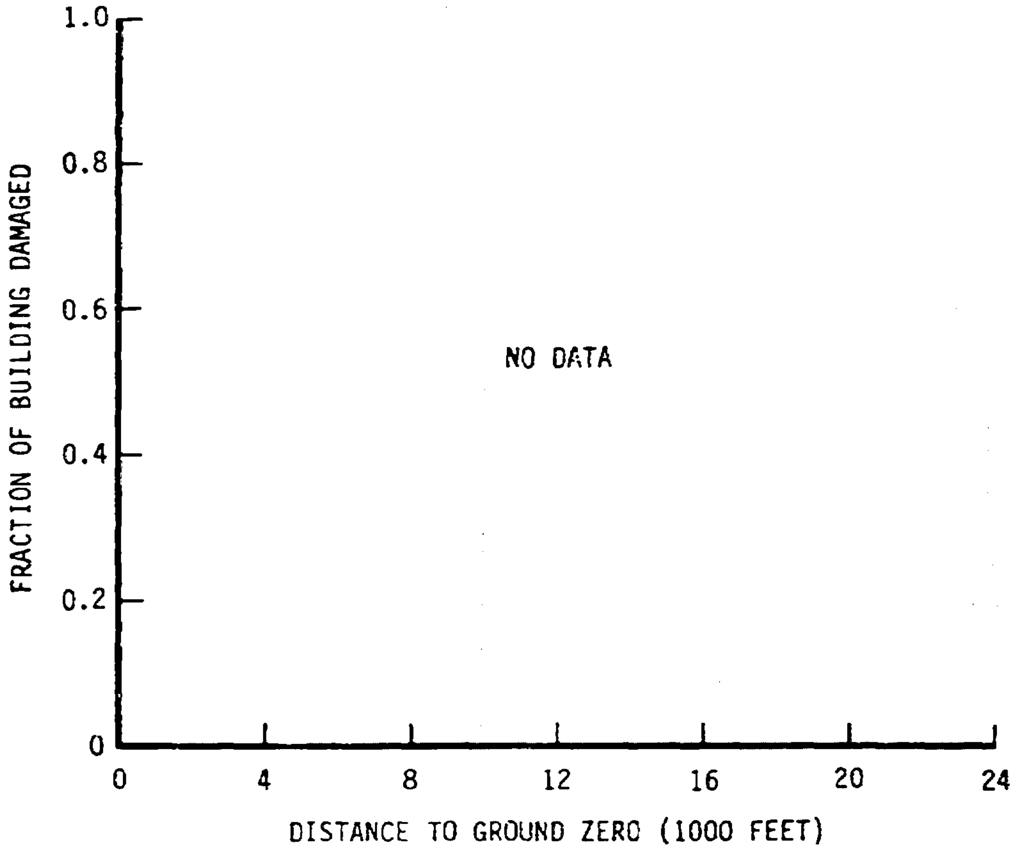


FIGURE 35b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI
STEEL ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY
STRUCTURAL DAMAGE TO ROOFS

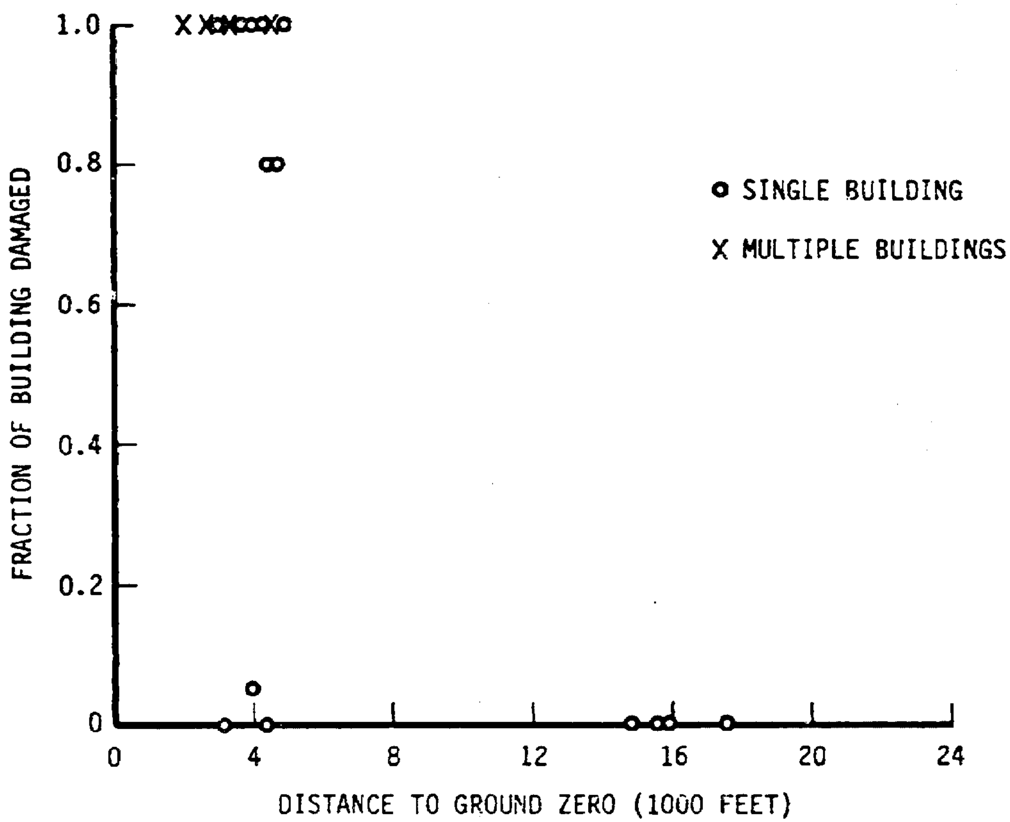


FIGURE 35c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA

STEEL ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO ROOFS

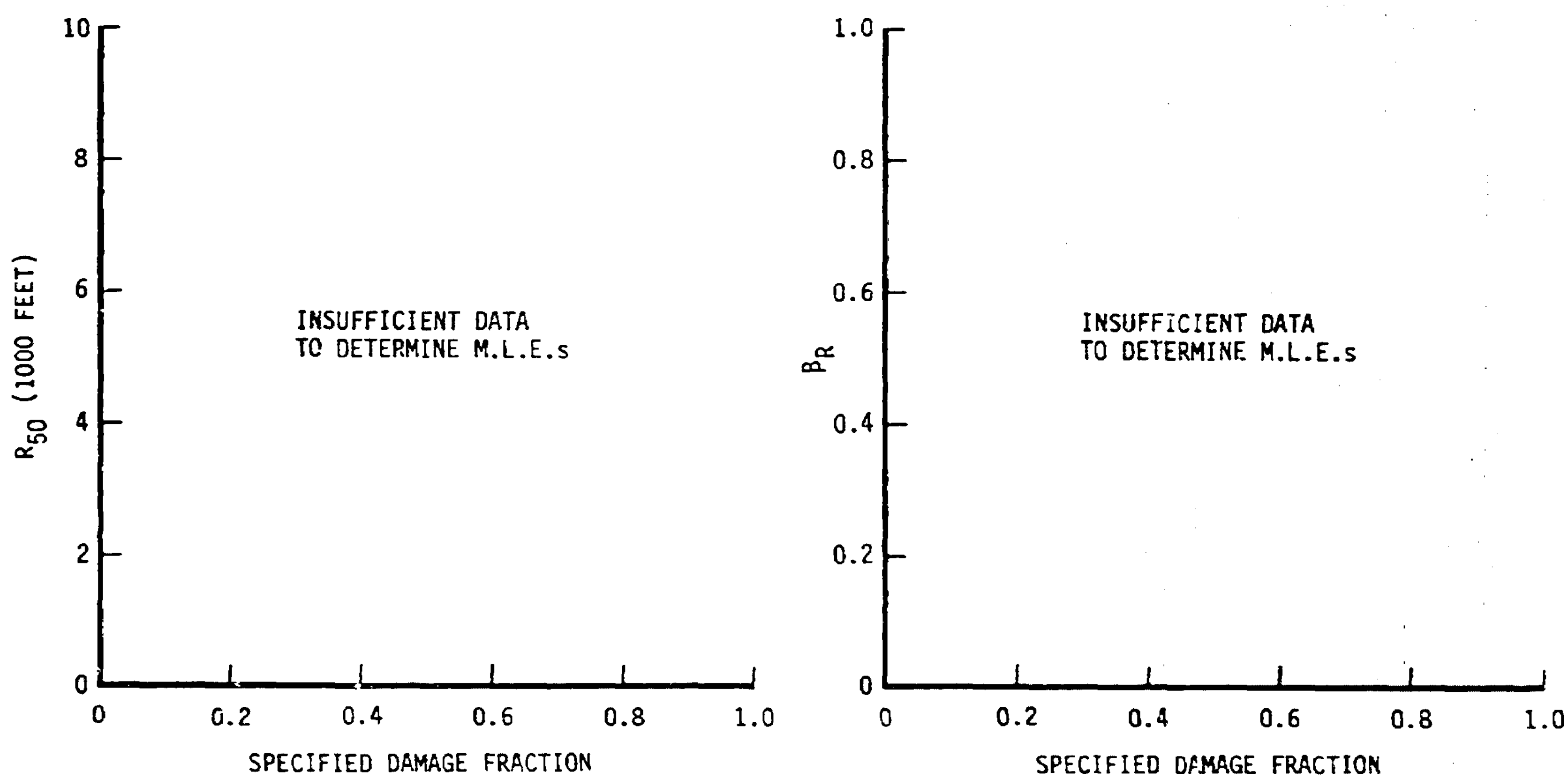


FIGURE 35d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI
STEEL ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY
STRUCTURAL DAMAGE TO ROOFS

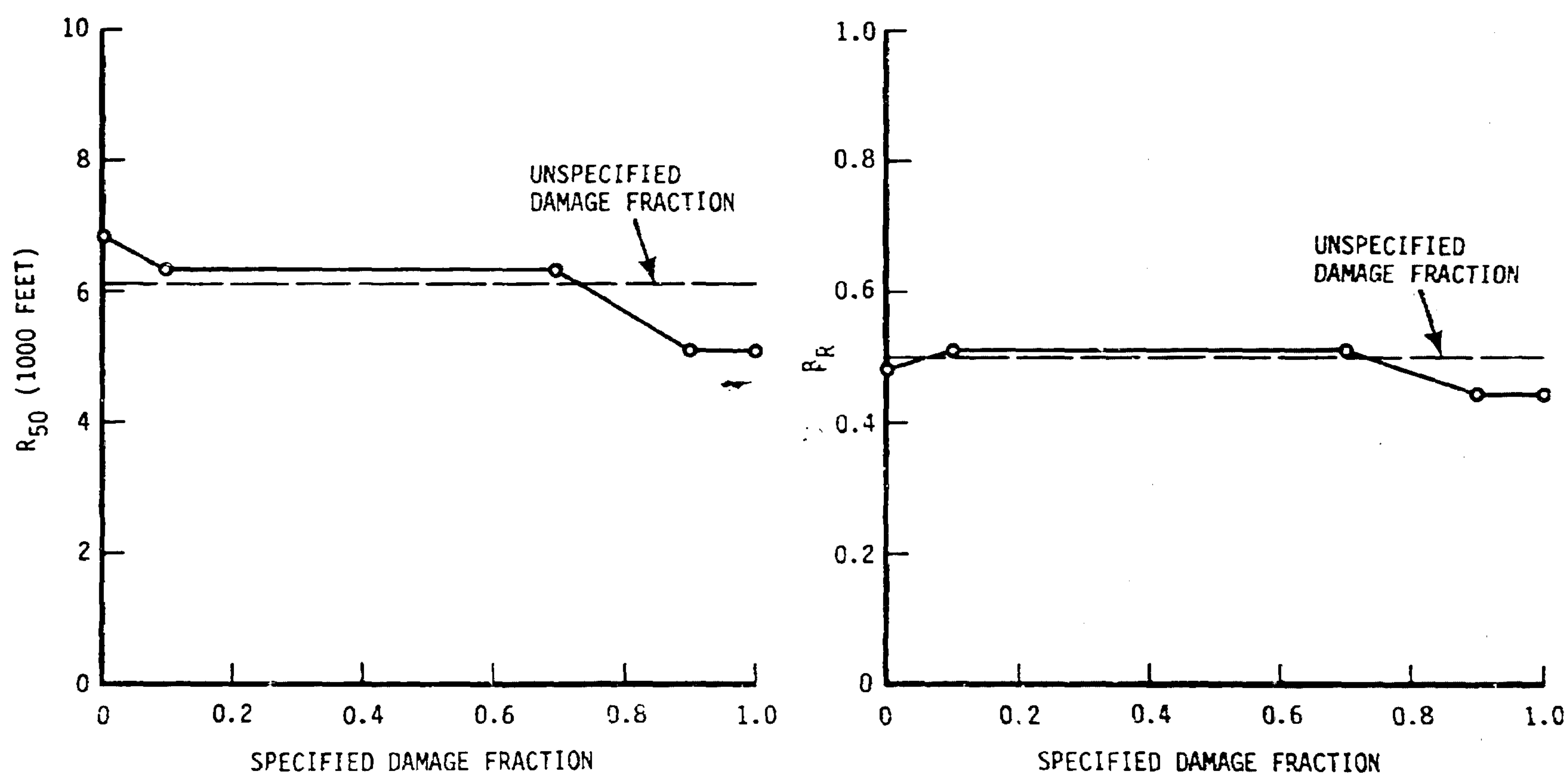


FIGURE 35e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF Q_{50} AND β_Q

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS

STEEL ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO ROOFS

HIROSHIMA YIELD ASSUMED = 12 KT

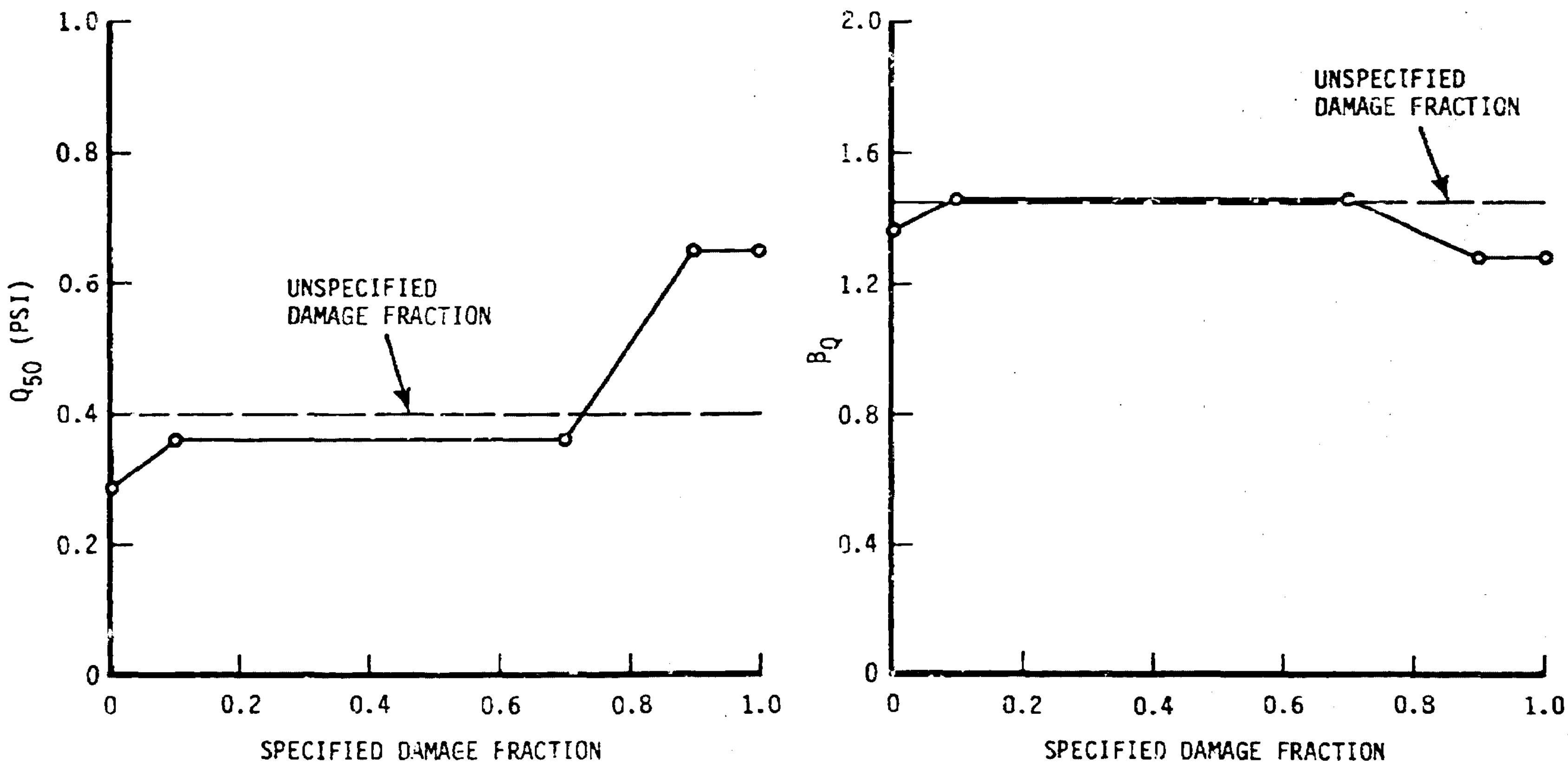


FIGURE 35f

CONFIDENCE REGIONS FOR Q_{50} AND β_Q

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS

STEEL ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO ROOFS

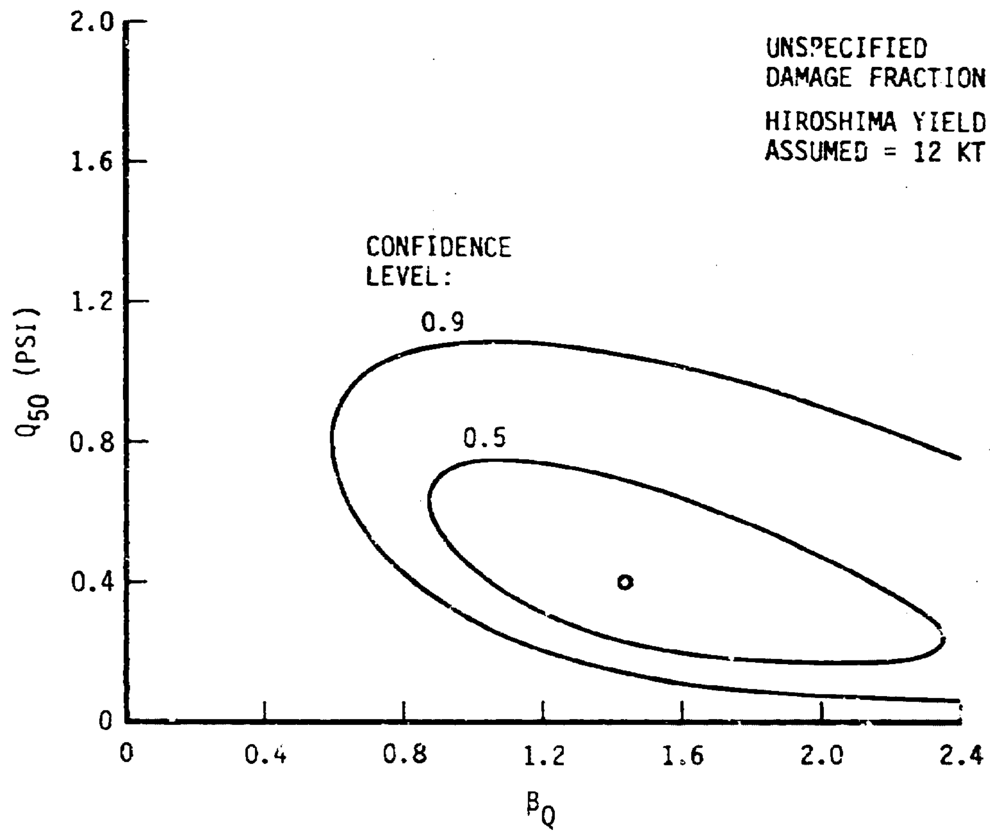


FIGURE 35g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA

STEEL ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY

STRUCTURAL DAMAGE TO ROOFS

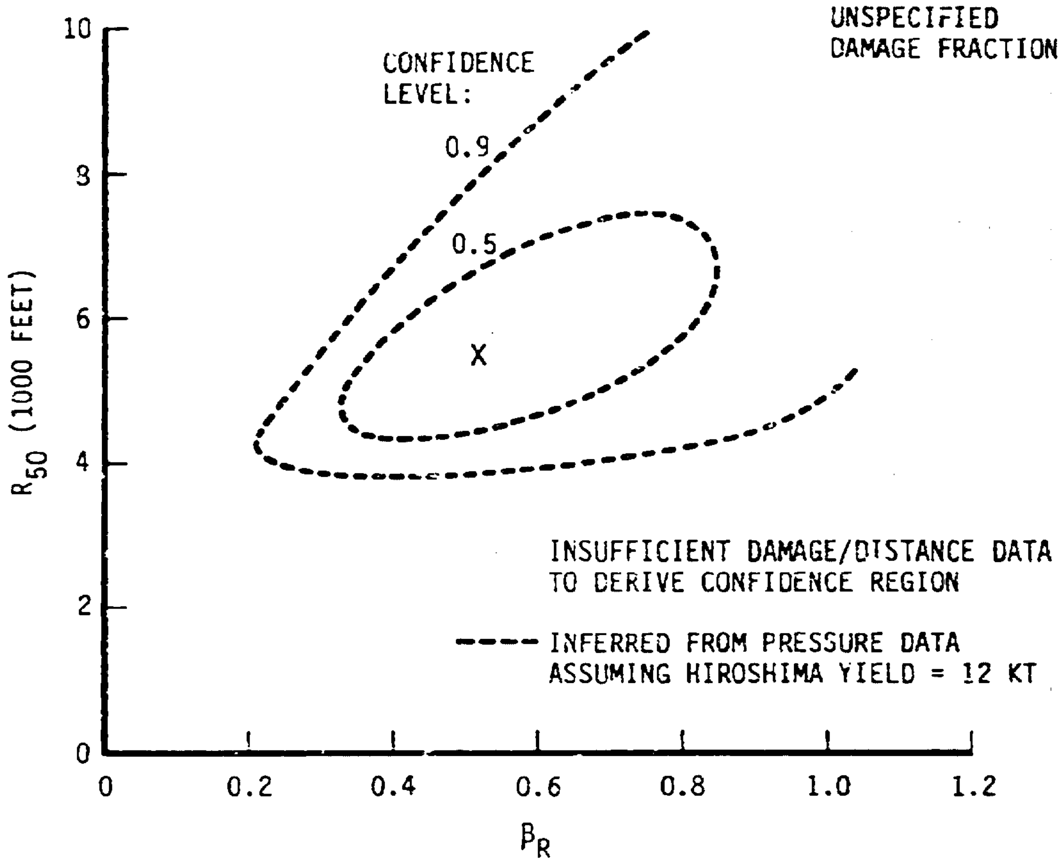


FIGURE 35h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY HEAVY STEEL FRAME BUILDINGS AT NAGASAKI
STEEL ROOF TRUSSES; ROOF COVER MATERIAL FAILS SLOWLY
STRUCTURAL DAMAGE TO ROOFS

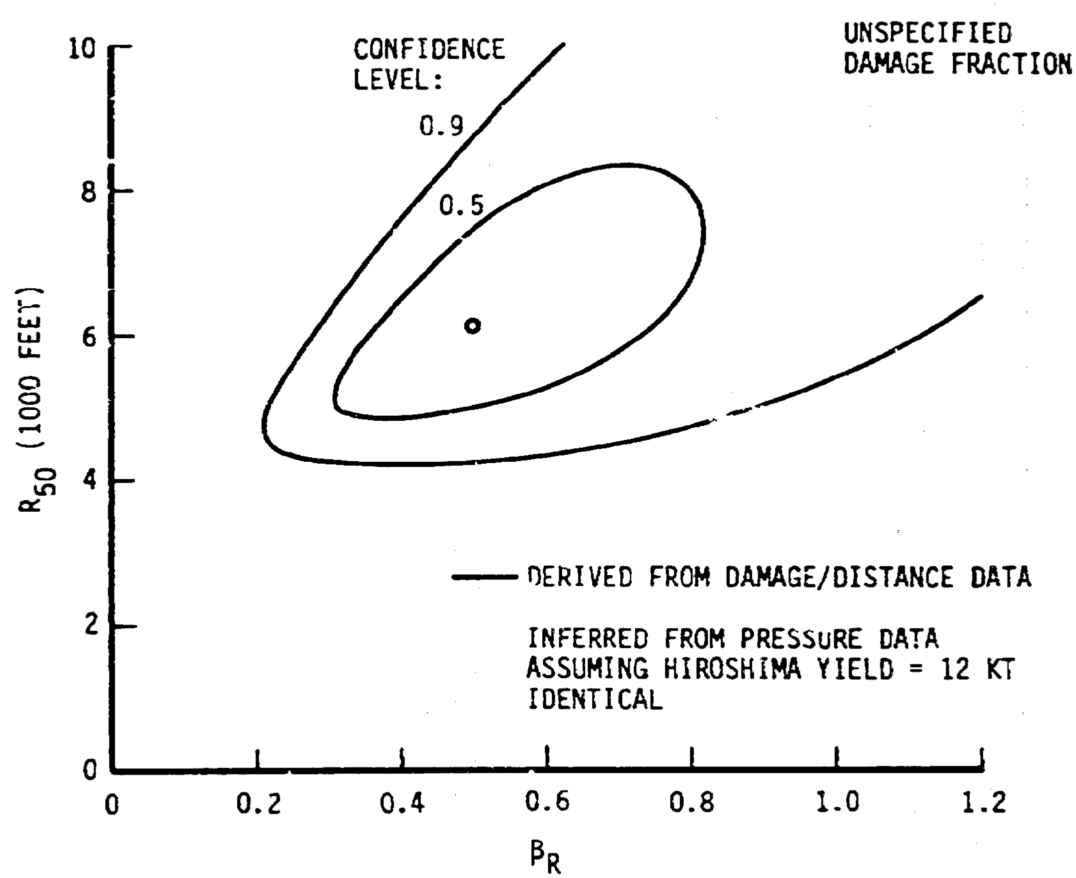


FIGURE 36a

DAMAGE VERSUS DISTANCE DATA

HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA
SUPERFICIAL DAMAGE CRITERIA

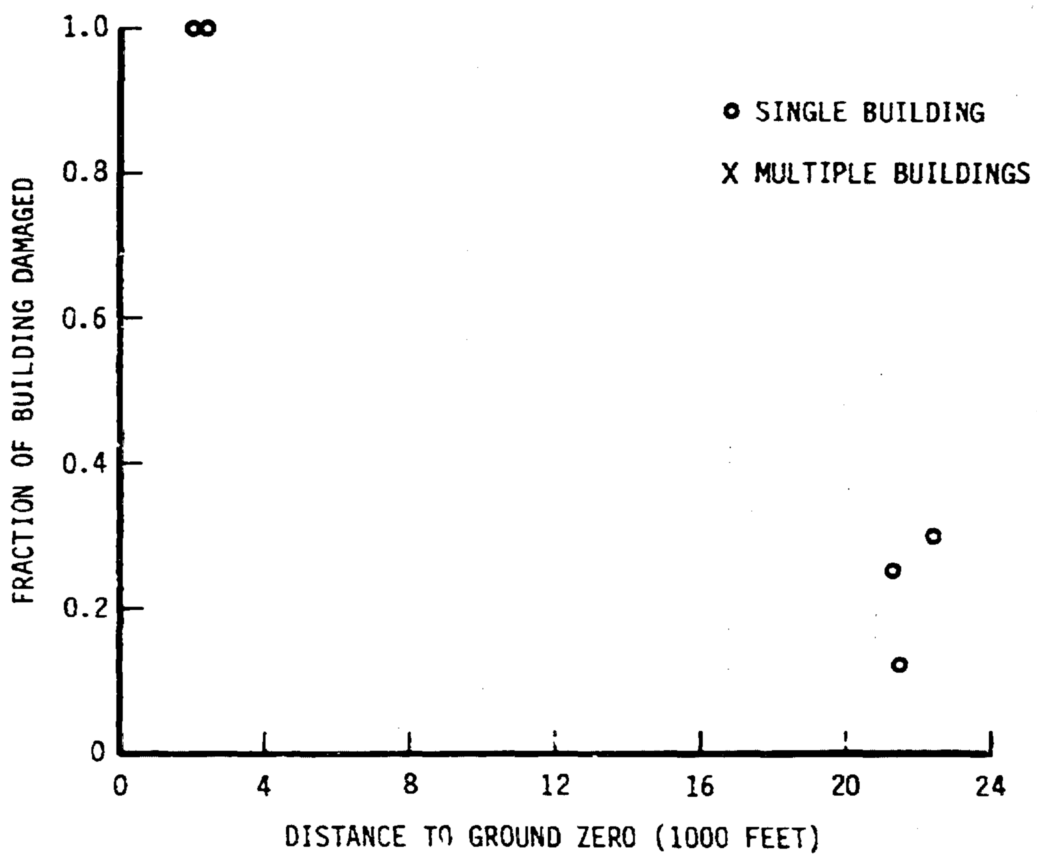


FIGURE 36b

DAMAGE VERSUS DISTANCE DATA

HEAVY STEEL FRAME BUILDINGS AT NAGASAKI
SUPERFICIAL DAMAGE CRITERIA

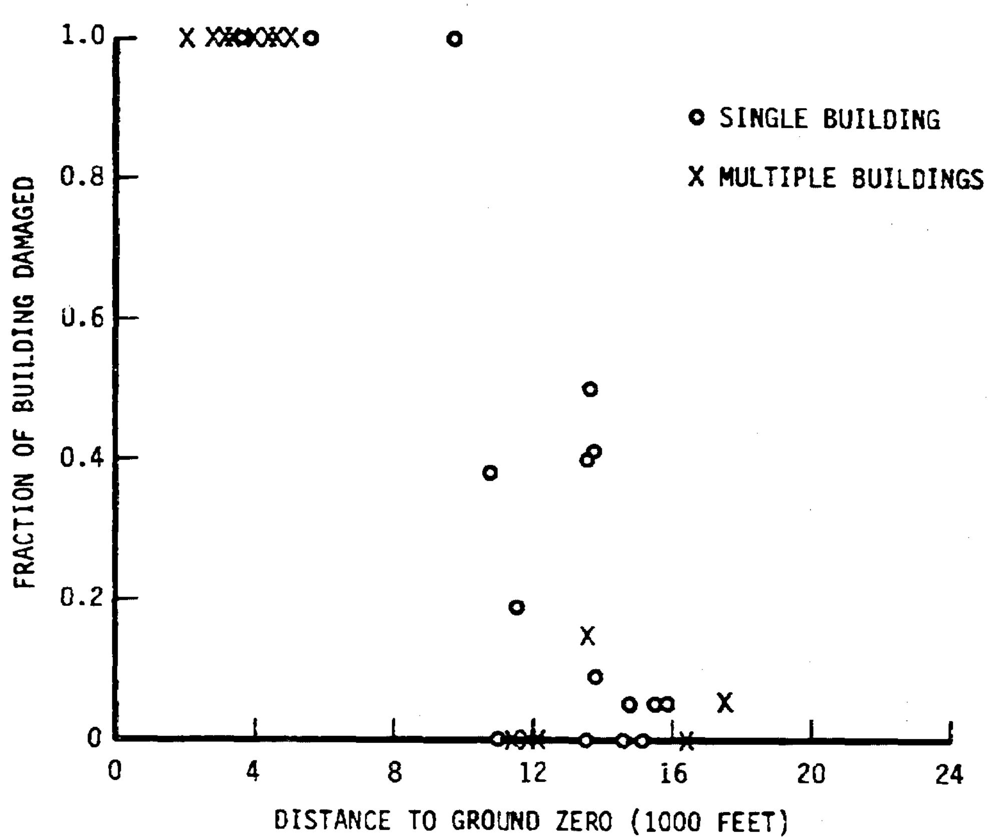


FIGURE 36c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA

SUPERFICIAL DAMAGE CRITERIA

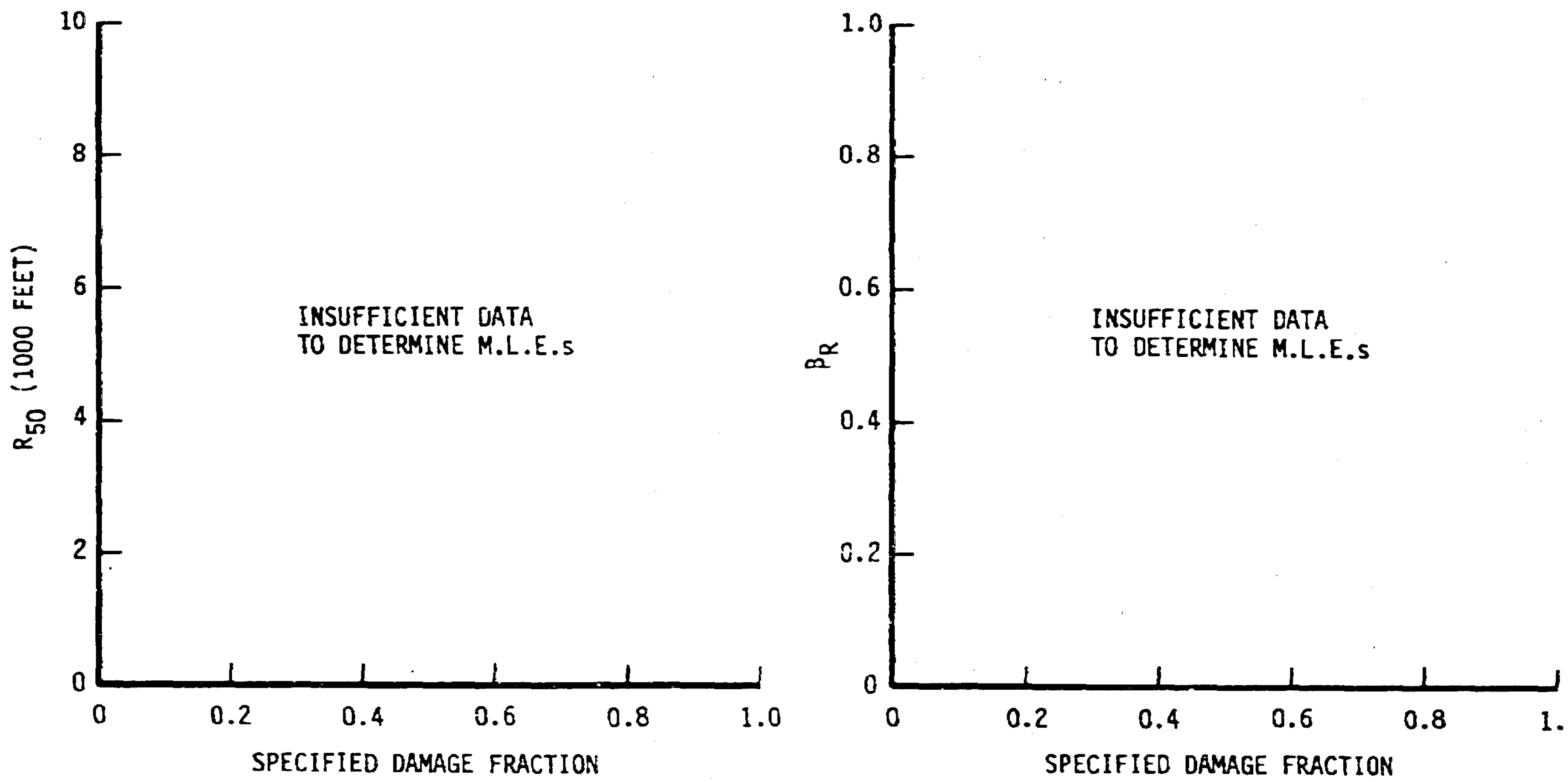


FIGURE 36d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

HEAVY STEEL FRAME BUILDINGS AT NAGASAKI

SUPERFICIAL DAMAGE CRITERIA

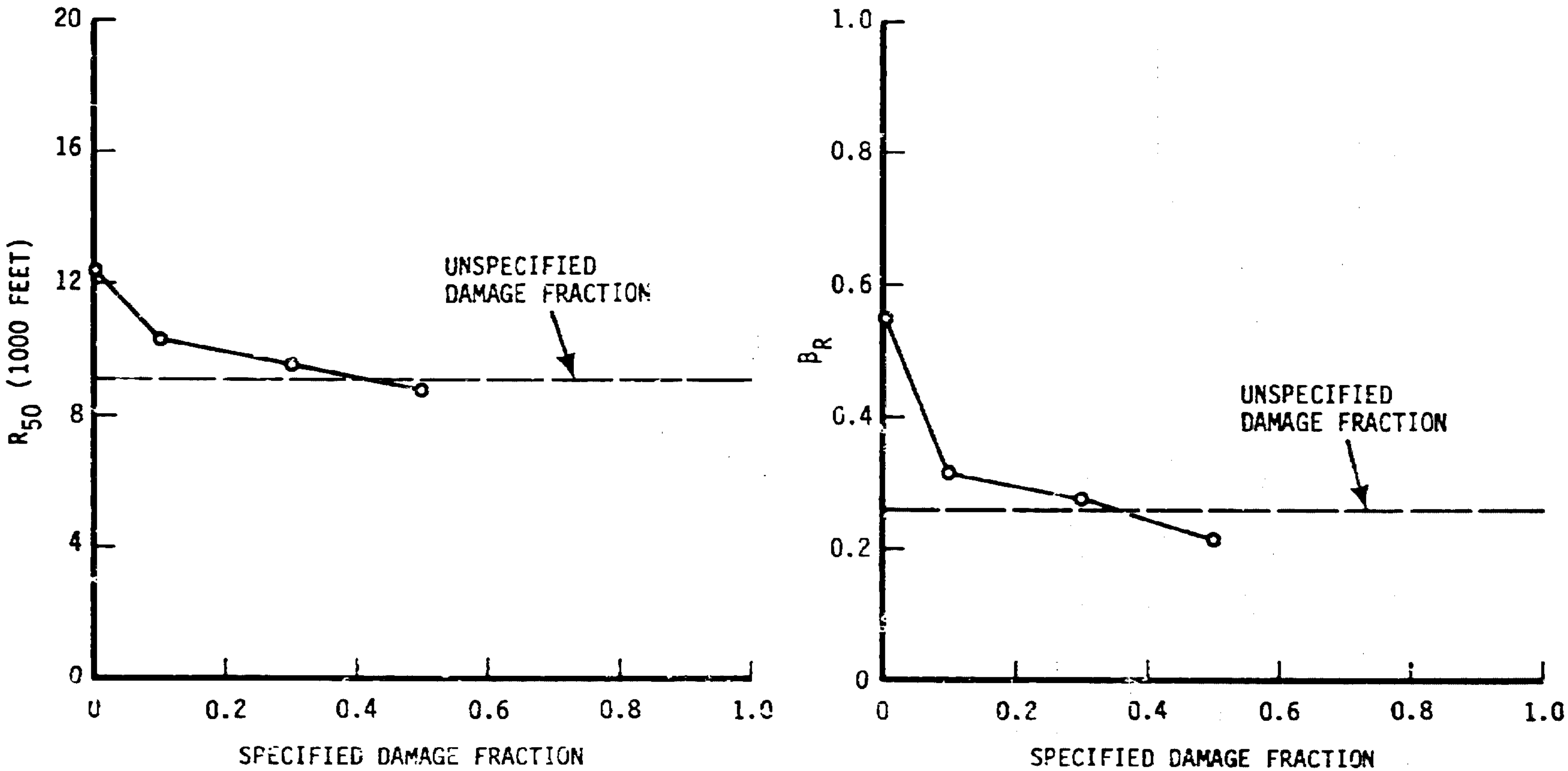


FIGURE 36e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

HEAVY STEEL FRAME BUILDINGS

SUPERFICIAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT

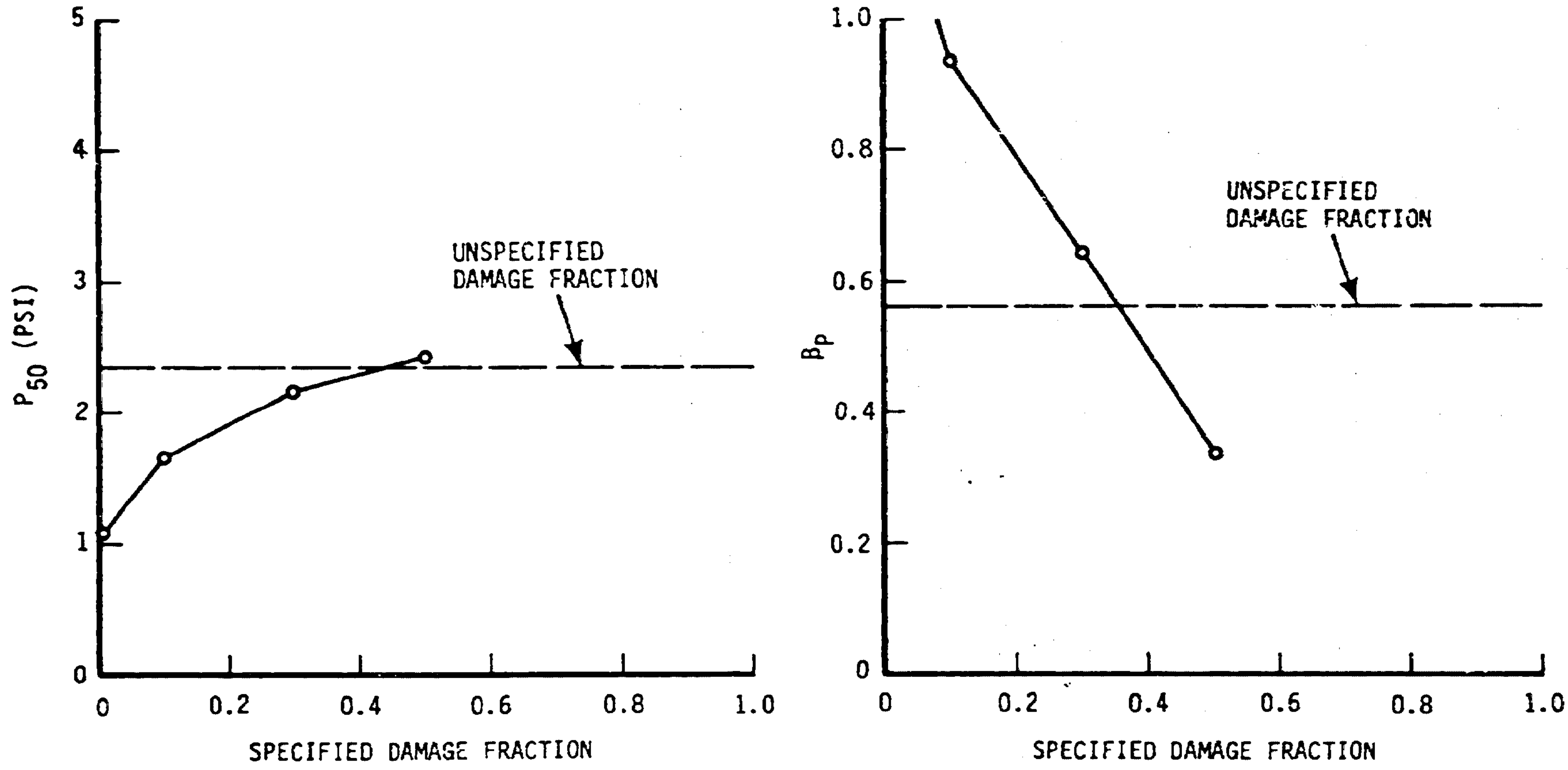


FIGURE 36f

CONFIDENCE REGIONS FOR P_{50} AND β_P

HEAVY STEEL FRAME BUILDINGS

SUPERFICIAL DAMAGE CRITERIA

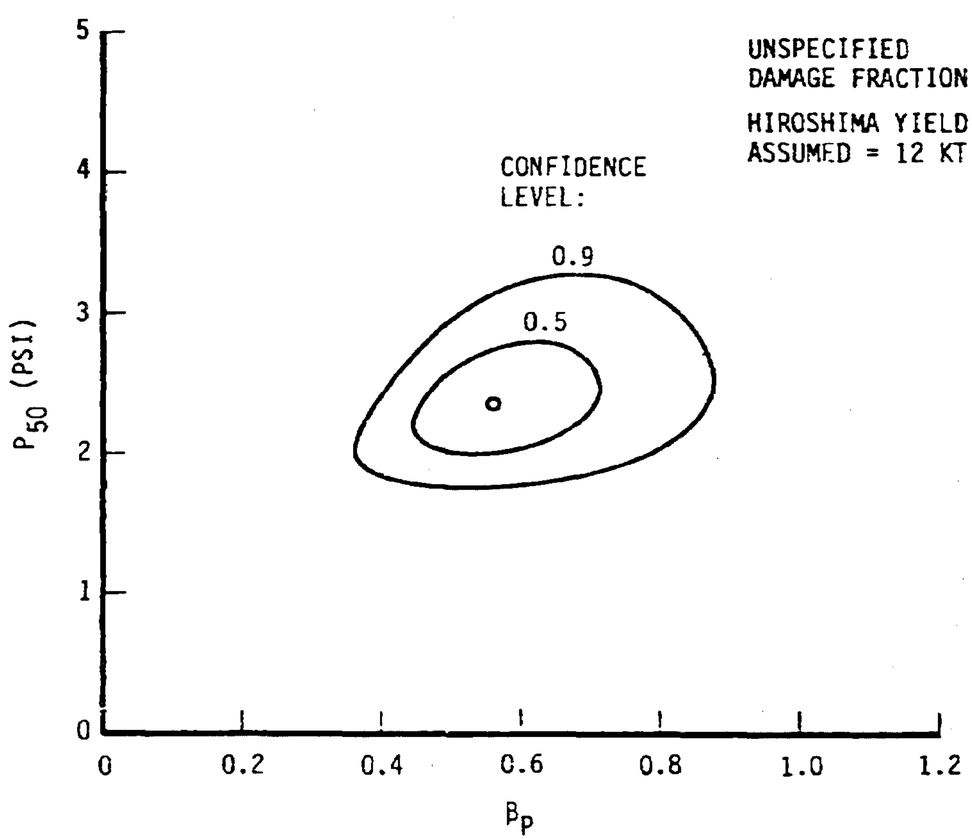


FIGURE 36g

CONFIDENCE REGIONS FOR R_{50} AND β_R

HEAVY STEEL FRAME BUILDINGS AT HIROSHIMA

SUPERFICIAL DAMAGE CRITERIA

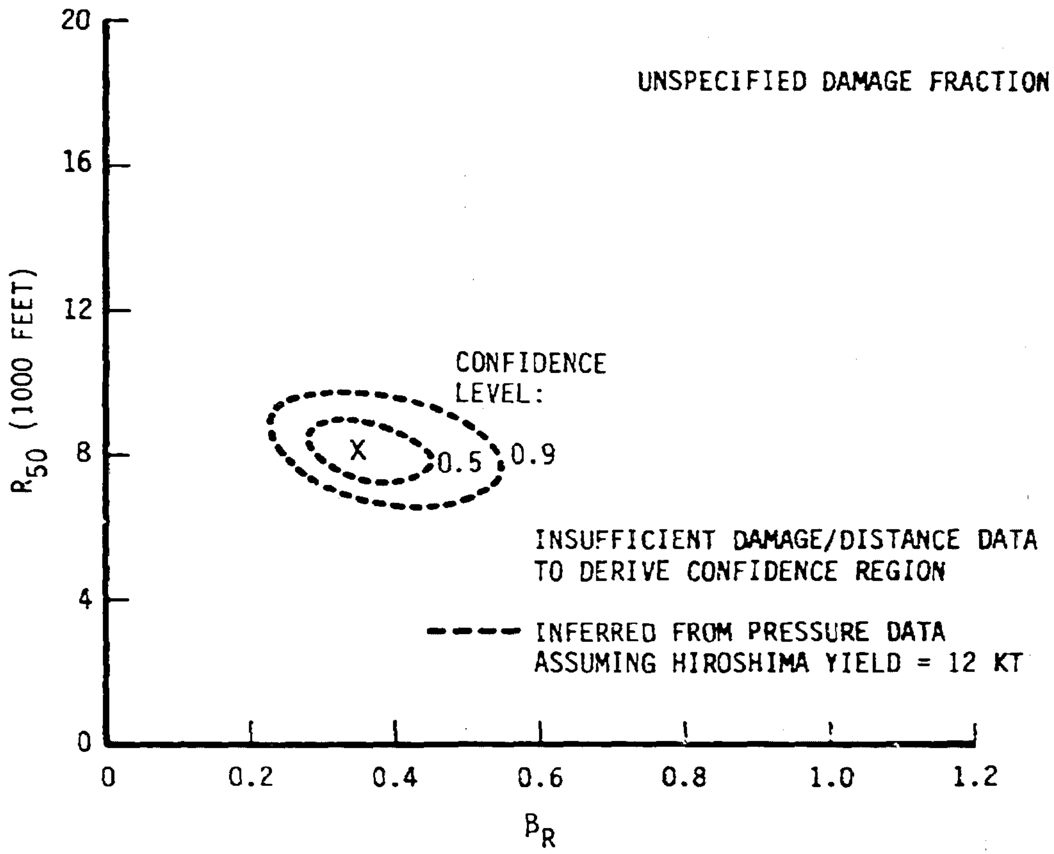
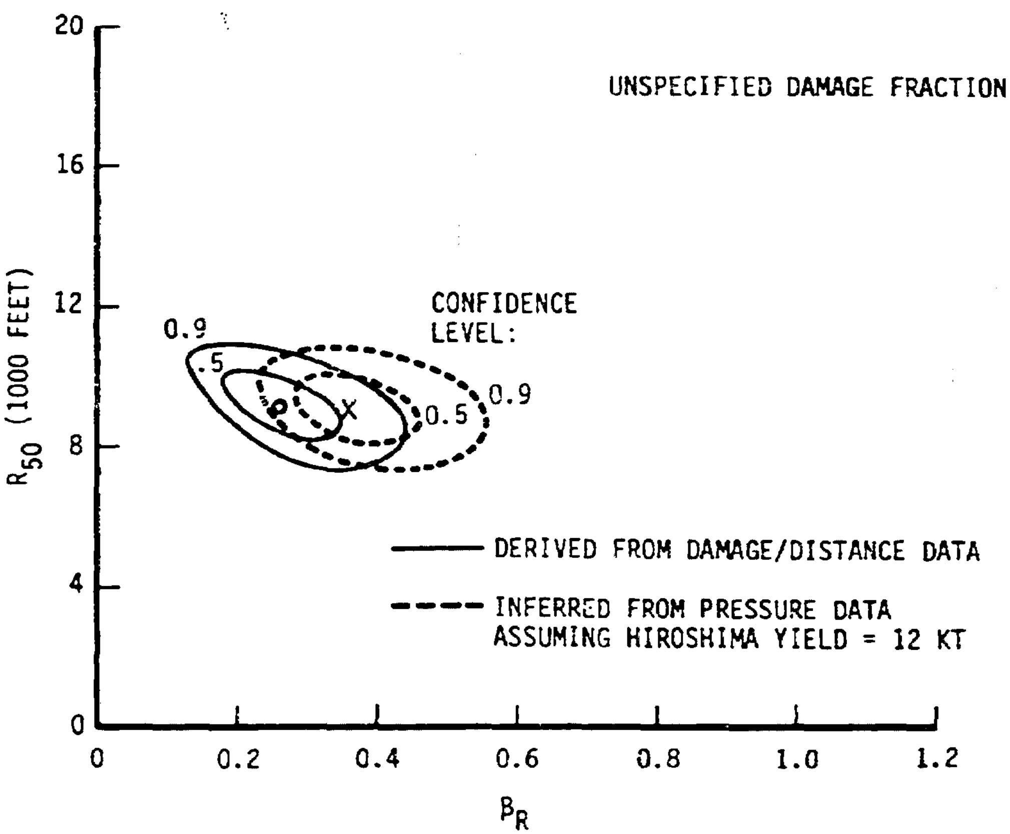


FIGURE 36h

CONFIDENCE REGIONS FOR R_{50} AND B_R

HEAVY STEEL FRAME BUILDINGS AT NAGASAKI

SUPERFICIAL DAMAGE CRITERIA



V. LIGHT AND HEAVY STEEL FRAME BUILDINGS

This grouping combines the Single-Story Light Steel Frame Buildings with the Single-Story Heavy Steel Frame Buildings to examine the superficial damage criteria. The data base includes 131 buildings, 46 in Hiroshima and 85 in Nagasaki. The breakdown by wall and roof types are shown below:

	NUMBER OF BUILDINGS	
WALL TYPE	Hiroshima	Nagasaki
1	16	64
2	24	15
3	2	0
4	0	6
6	2	0
9	2	0
TOTAL	46	85

	NUMBER OF BUILDINGS	
ROOF TYPE	Hiroshima	Nagasaki
2	19	61
3	21	24
5	4	0
9	2	0
TOTAL	46	85

There are sufficient numbers of both slow- and quick-failing wall and roof cover materials to permit their isolation for this combination of data. The following table shows the cases examined and a summary of the data.

SUMMARY OF STEEL FRAME BUILDINGS

TYPE	M.L.E.		MAX. 90% CONF. LIM.		DATA POINTS TOTAL		DATA POINTS ±1 SIGMA	
	P_{50}	β_P	P_{50}	β_P	H	N	H	N
SINGLE-STORY								
1. Superficial								
a. All	1.91	.46	1.55-2.30	.33- .66	46	85	11	20
b. Slow Wall, Roof	2.25	.32	1.75-3.05	.17- .60	9	45	1	3
c. Quick Wall, Roof	1.28	.55	.80-2.15	.30-1.26	18	8	9	1

The Superficial Damage criteria for the combined Single-Story Steel Frame Buildings gives a more reliable data base. The mean pressure of 1.91 compares with the Light Steel Frame value of 1.90 and the less reliable Heavy Steel Frame value of 2.35. The σ_d of this set is 28, similar to the other building types. The σ_d's for Light and Heavy Steel Frame Buildings are 23 and 34, respectively.

It was also possible to isolate the slow- and quick-failing wall and roof types for analysis. Although the results are not quite as reliable as evidenced by the larger confidence intervals and smaller data sets, it gives an indication of the effect of wall and roof cover material on Superficial Damage.

FIGURE 37a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY STEEL FRAME BUILDINGS AT HIROSHIMA
SUPERFICIAL DAMAGE CRITERIA

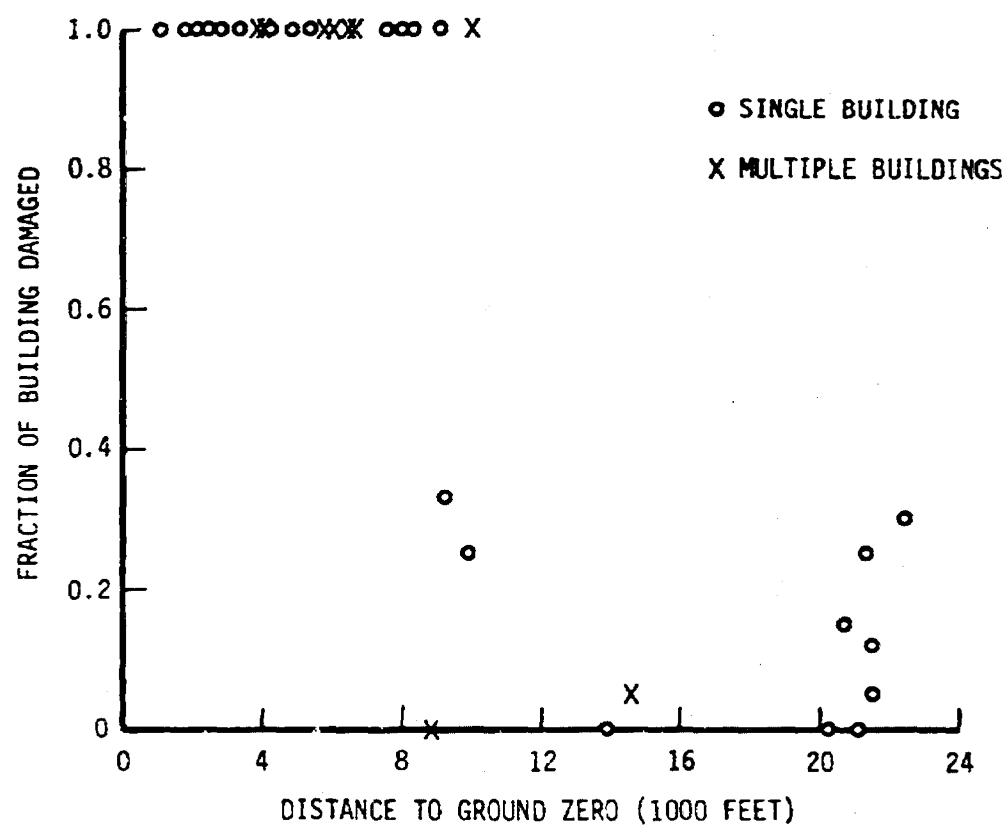


FIGURE 37b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY STEEL FRAME BUILDINGS AT NAGASAKI

SUPERFICIAL DAMAGE CRITERIA

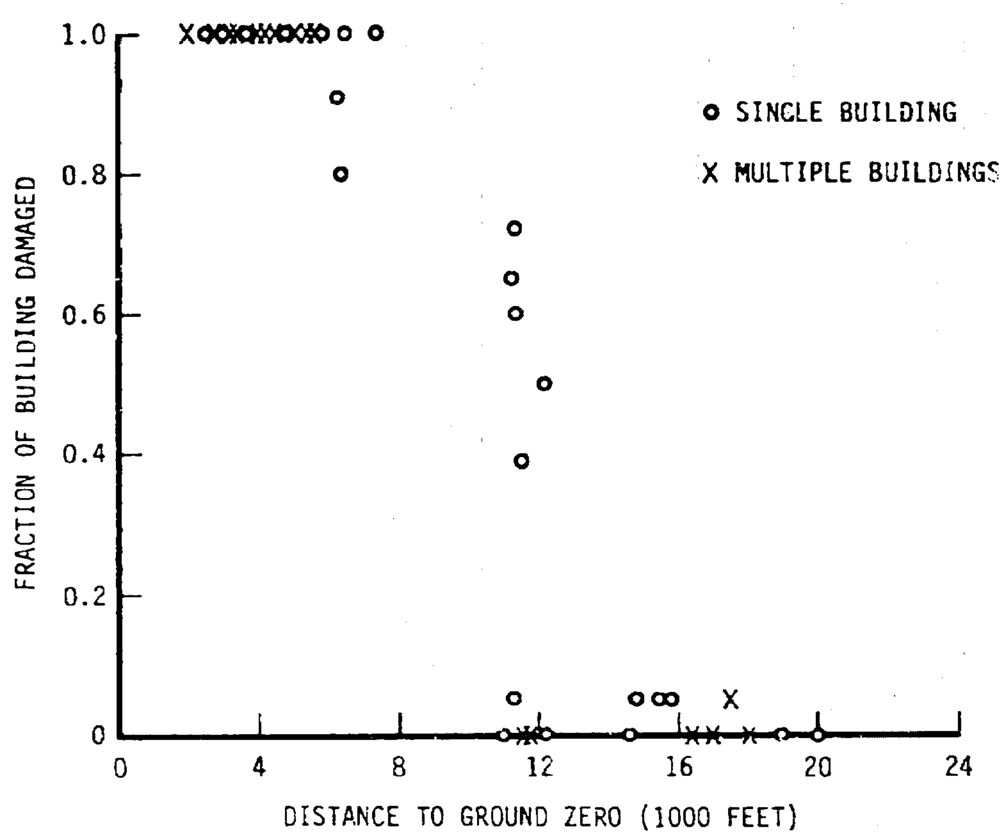
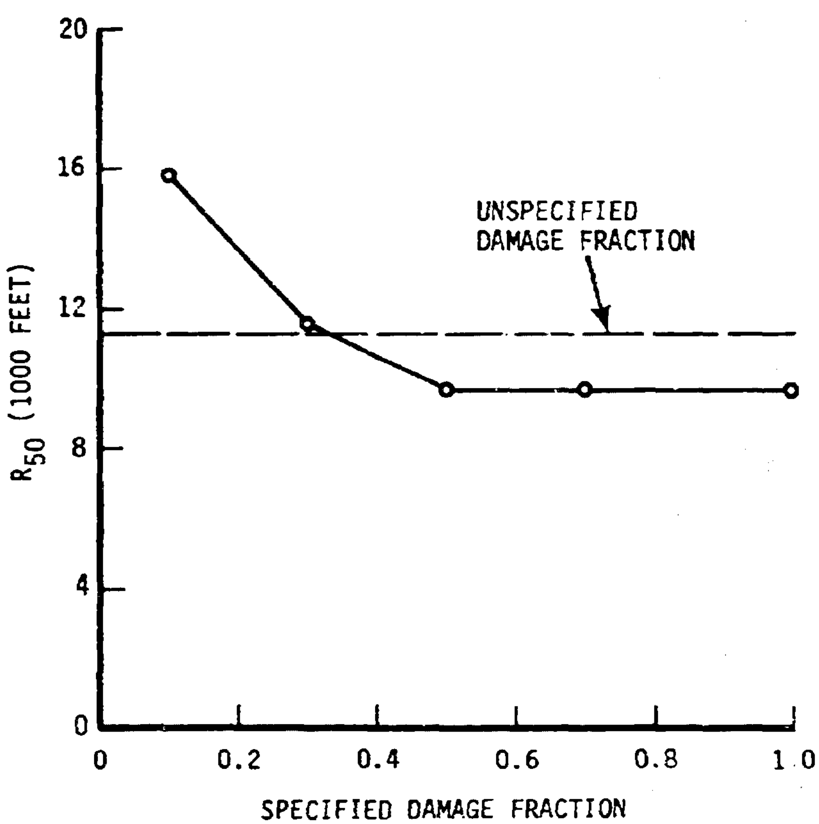


FIGURE 37c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY STEEL FRAME BUILDINGS AT HIROSHIMA

SUPERFICIAL DAMAGE CRITERIA



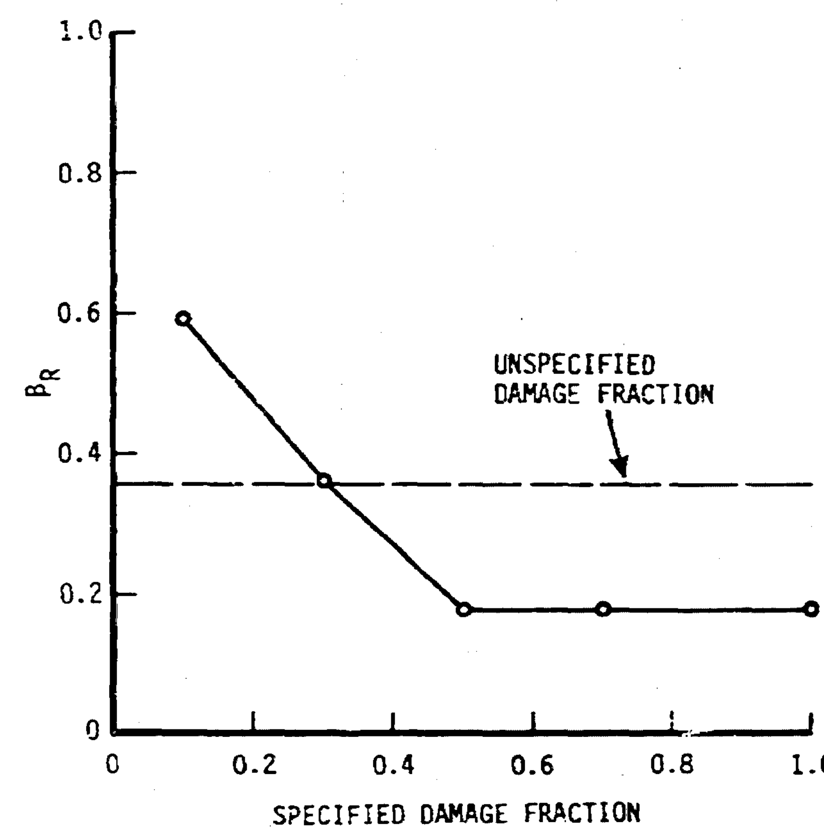


FIGURE 37d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY STEEL FRAME BUILDINGS AT NAGASAKI

SUPERFICIAL DAMAGE CRITERIA

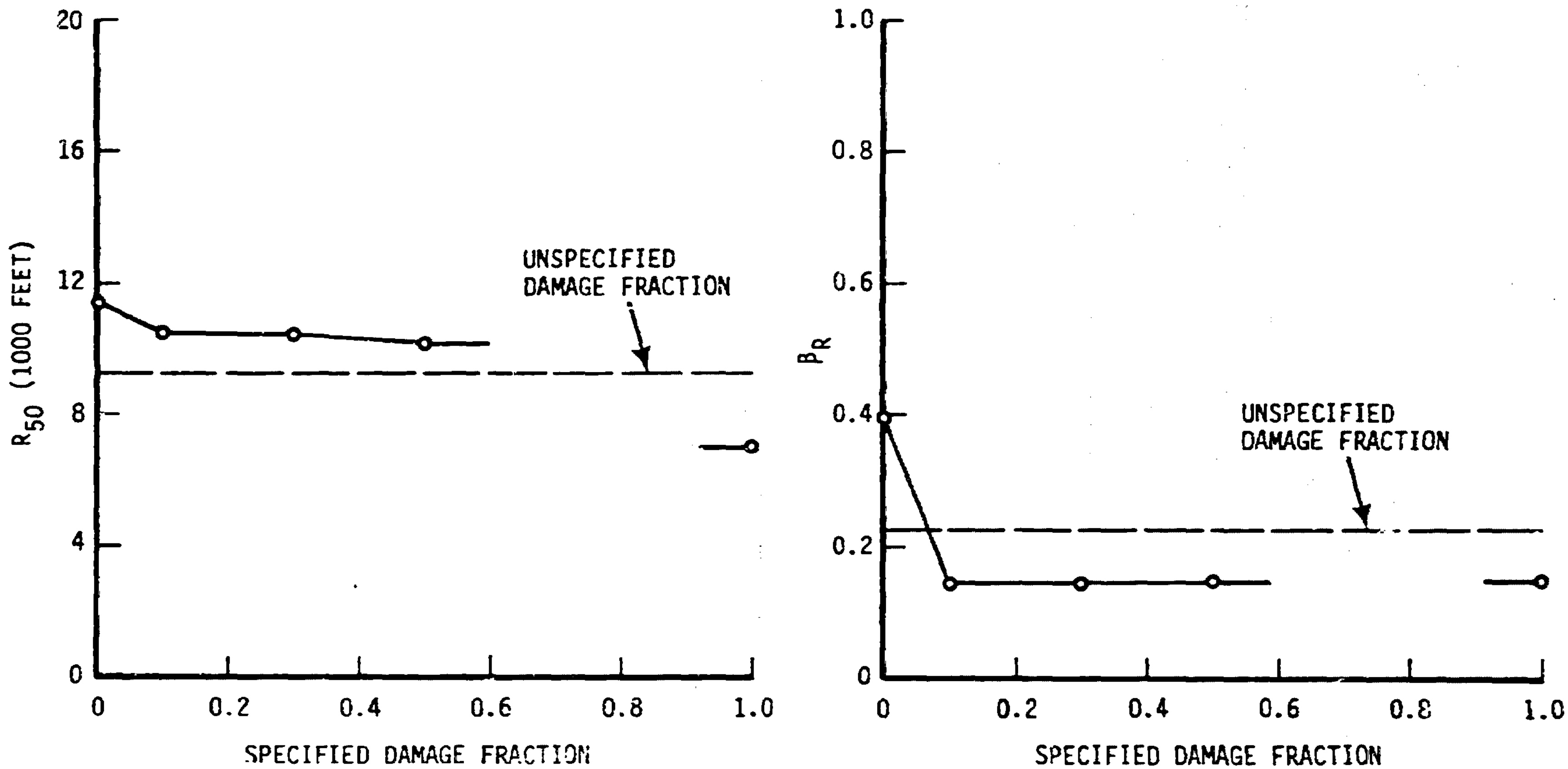


FIGURE 37e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF Q_{50} AND β_Q

SINGLE-STORY STEEL FRAME BUILDINGS
SUPERFICIAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT

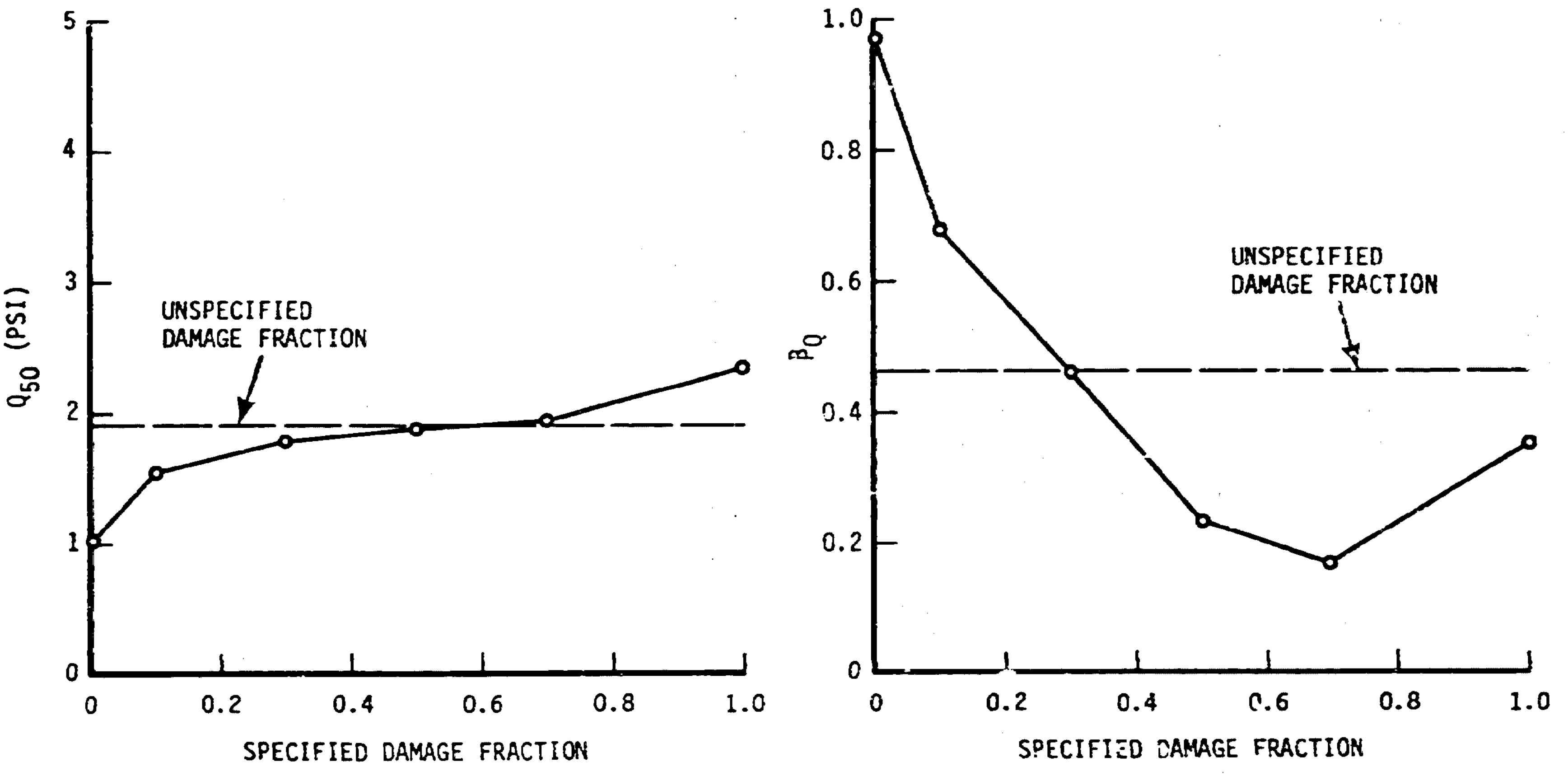


FIGURE 37f

CONFIDENCE REGIONS FOR Q_{50} AND β_Q

SINGLE-STORY STEEL FRAME BUILDINGS

SUPERFICIAL DAMAGE CRITERIA

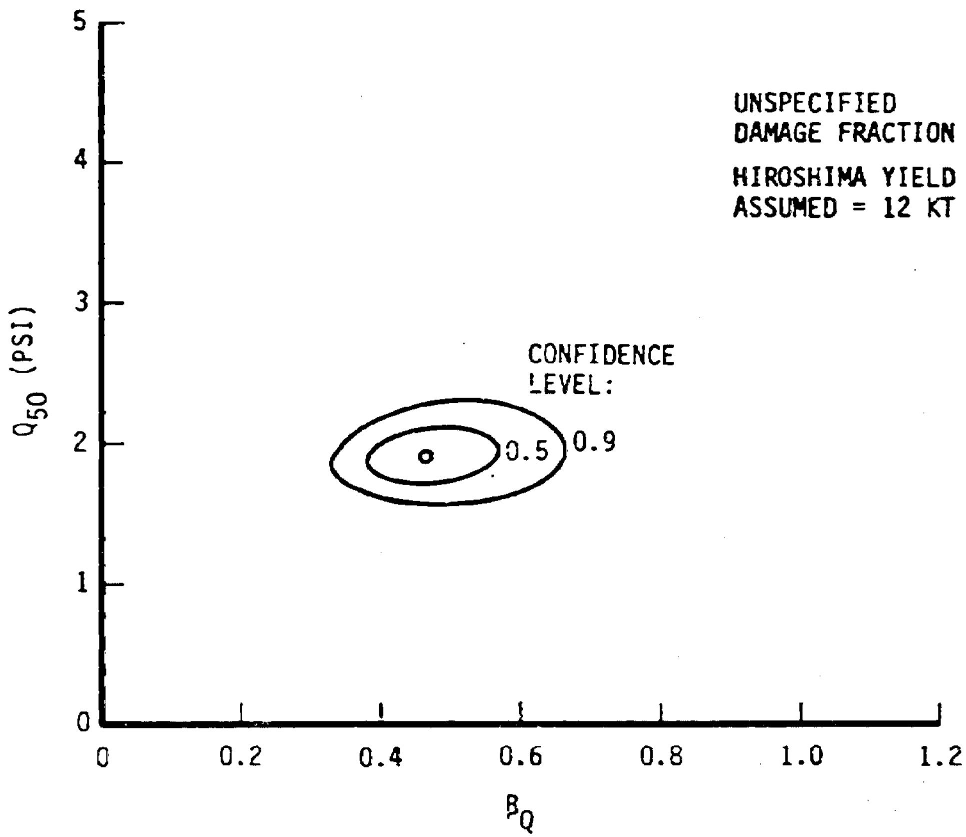


FIGURE 37g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY STEEL FRAME BUILDINGS AT HIROSHIMA

SUPERFICIAL DAMAGE CRITERIA

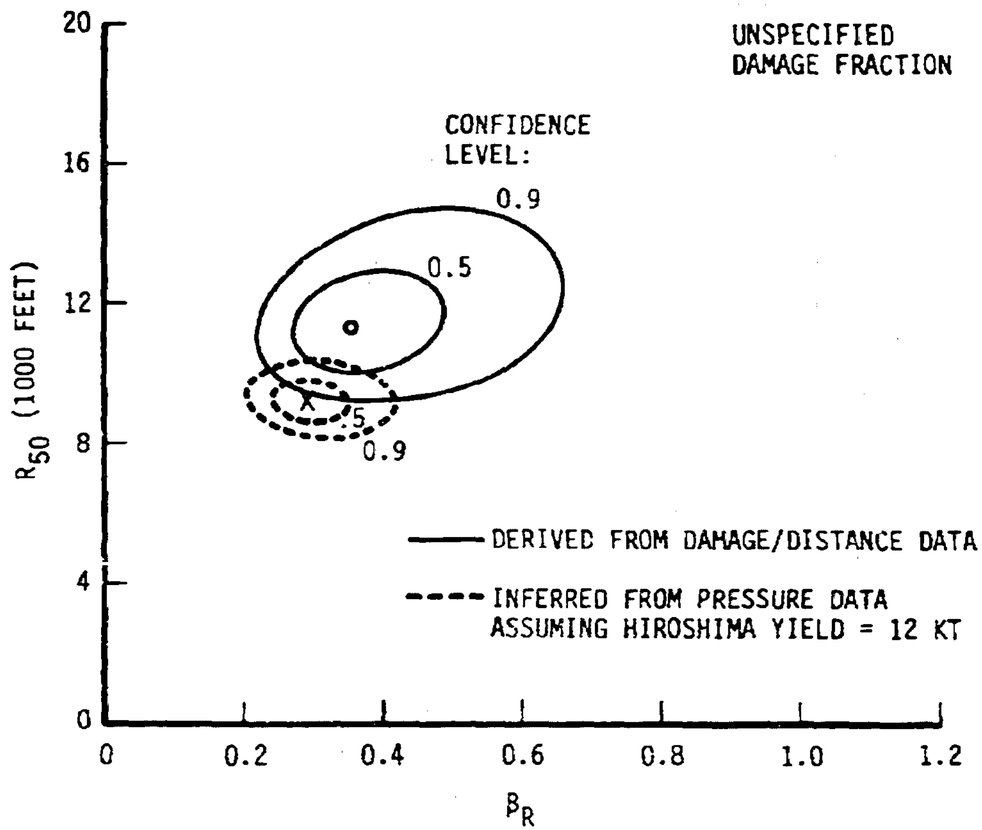


FIGURE 37h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY STEEL FRAME BUILDINGS AT NAGASAKI
SUPERFICIAL DAMAGE CRITERIA

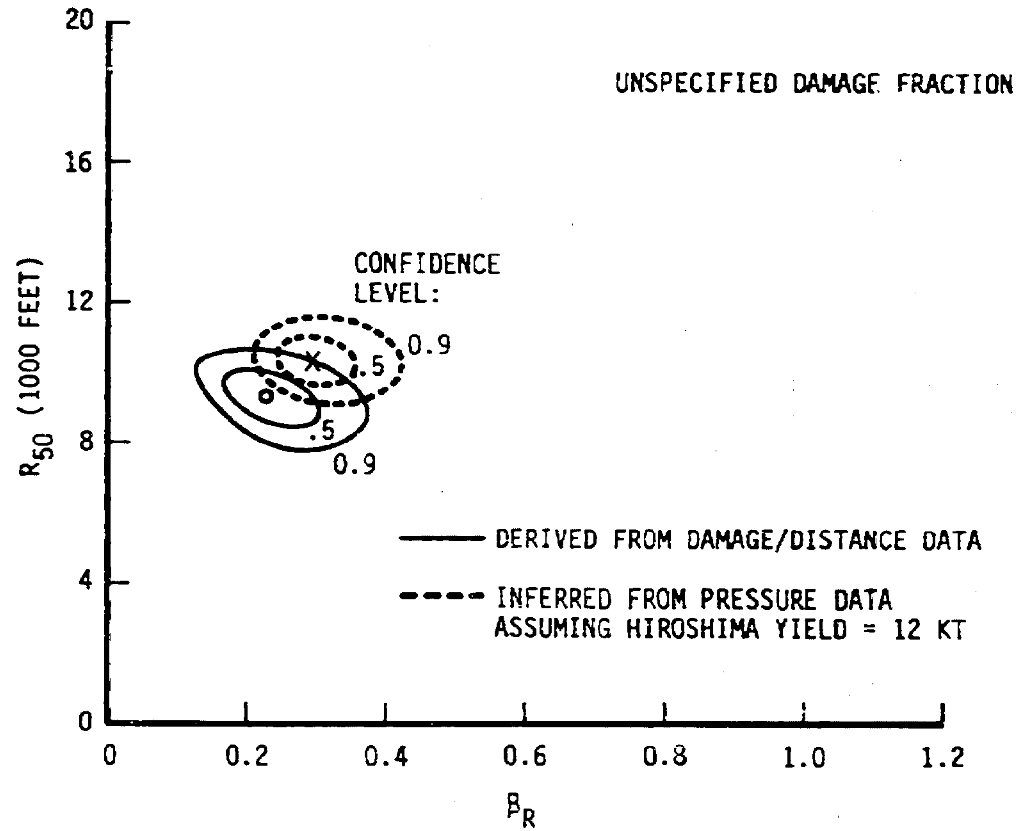


FIGURE 38a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY STEEL FRAME BUILDINGS AT HIROSHIMA

WALL & ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

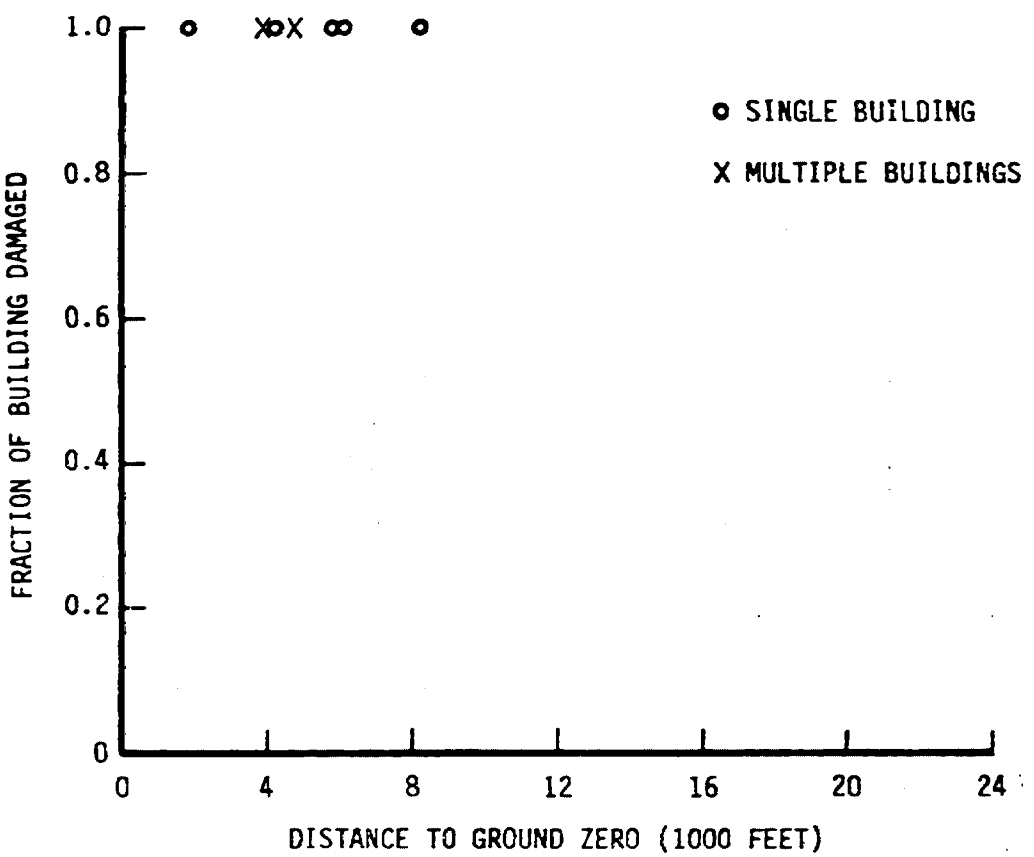


FIGURE 38b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY STEEL FRAME BUILDINGS AT NAGASAKI
WALL & ROOF COVER MATERIAL FAILS SLOWLY
SUPERFICIAL DAMAGE CRITERIA

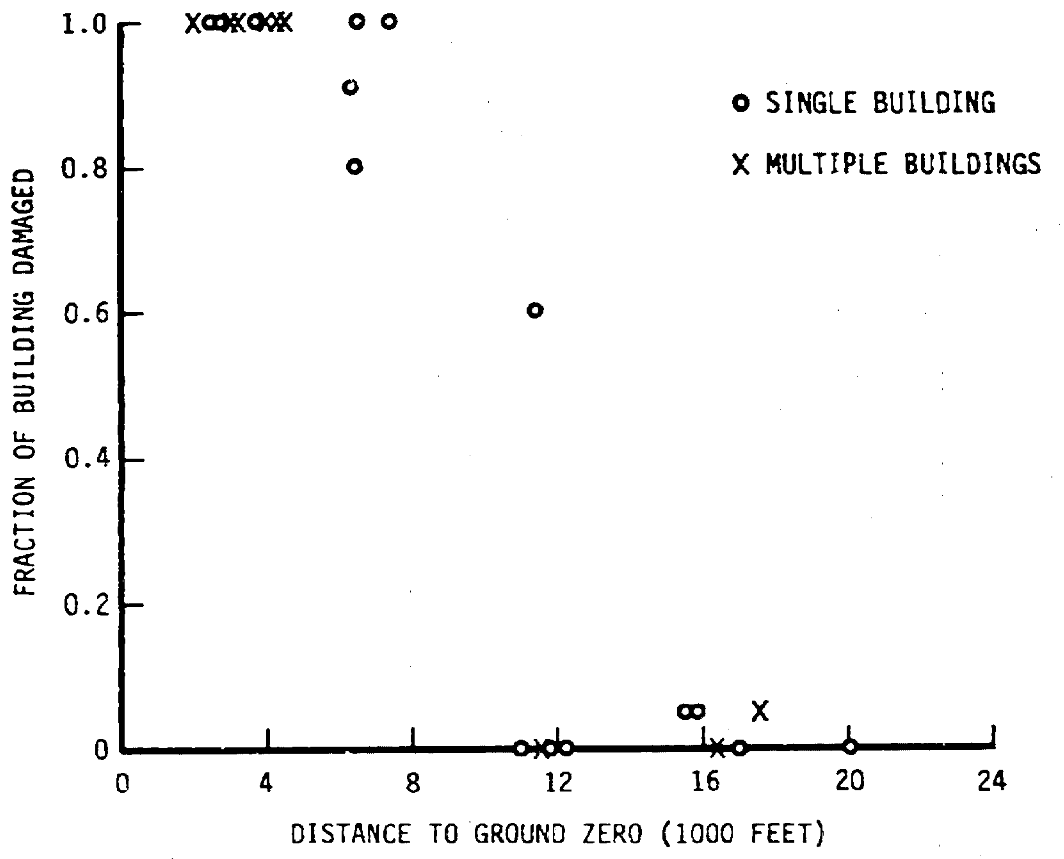


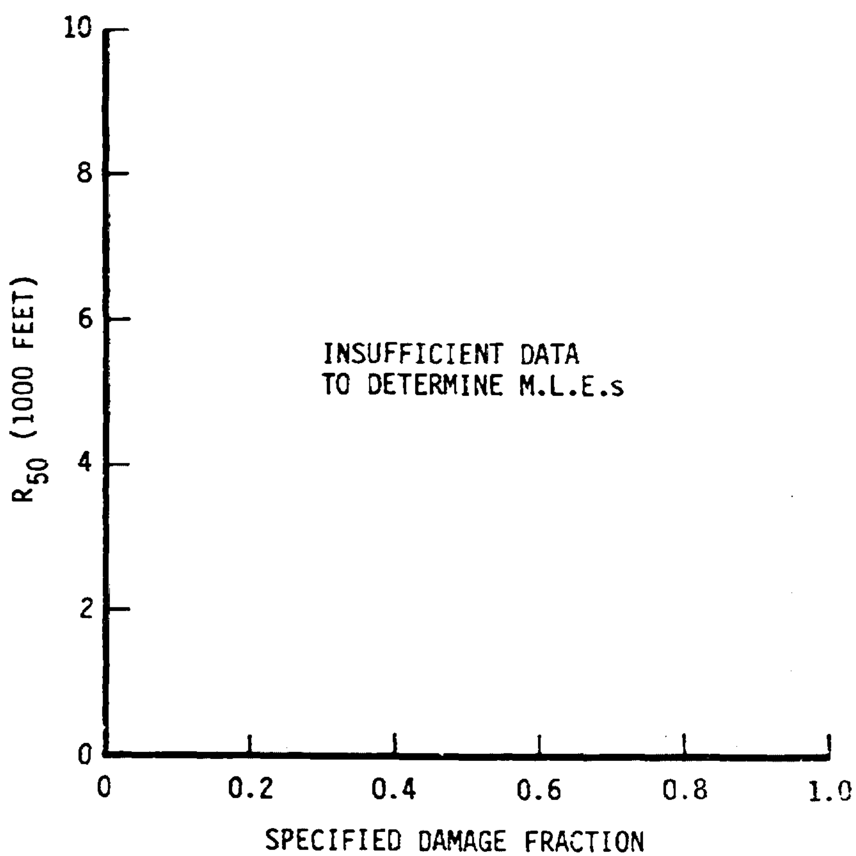
FIGURE 38c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY STEEL FRAME BUILDINGS AT HIROSHIMA

WALL & ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA



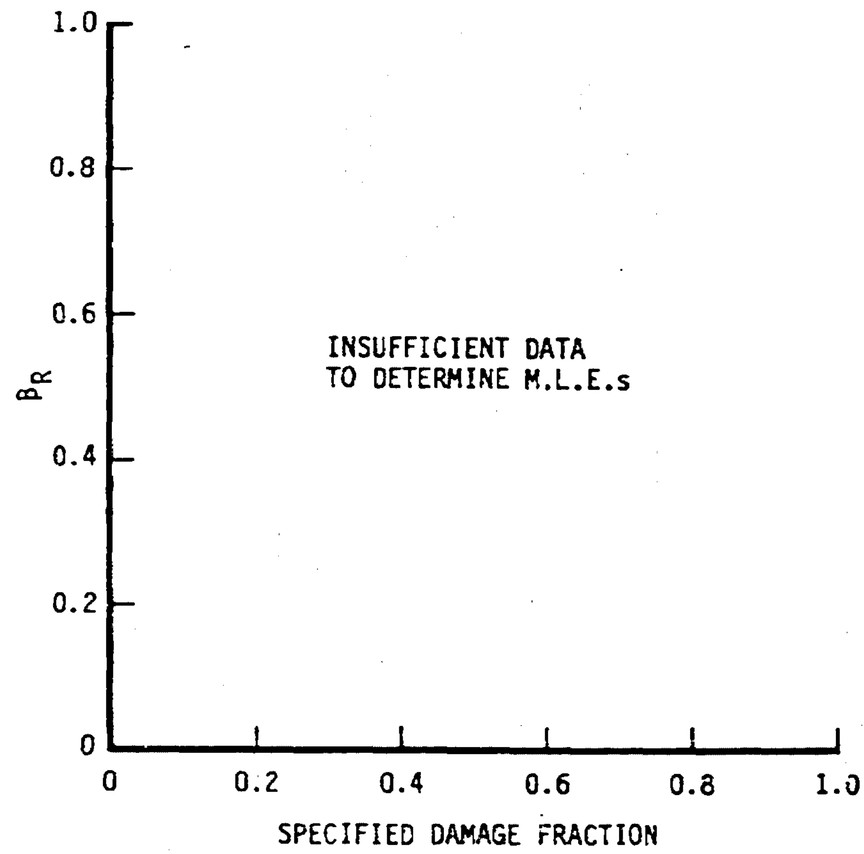


FIGURE 38d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY STEEL FRAME BUILDINGS AT NAGASAKI

WALL & ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

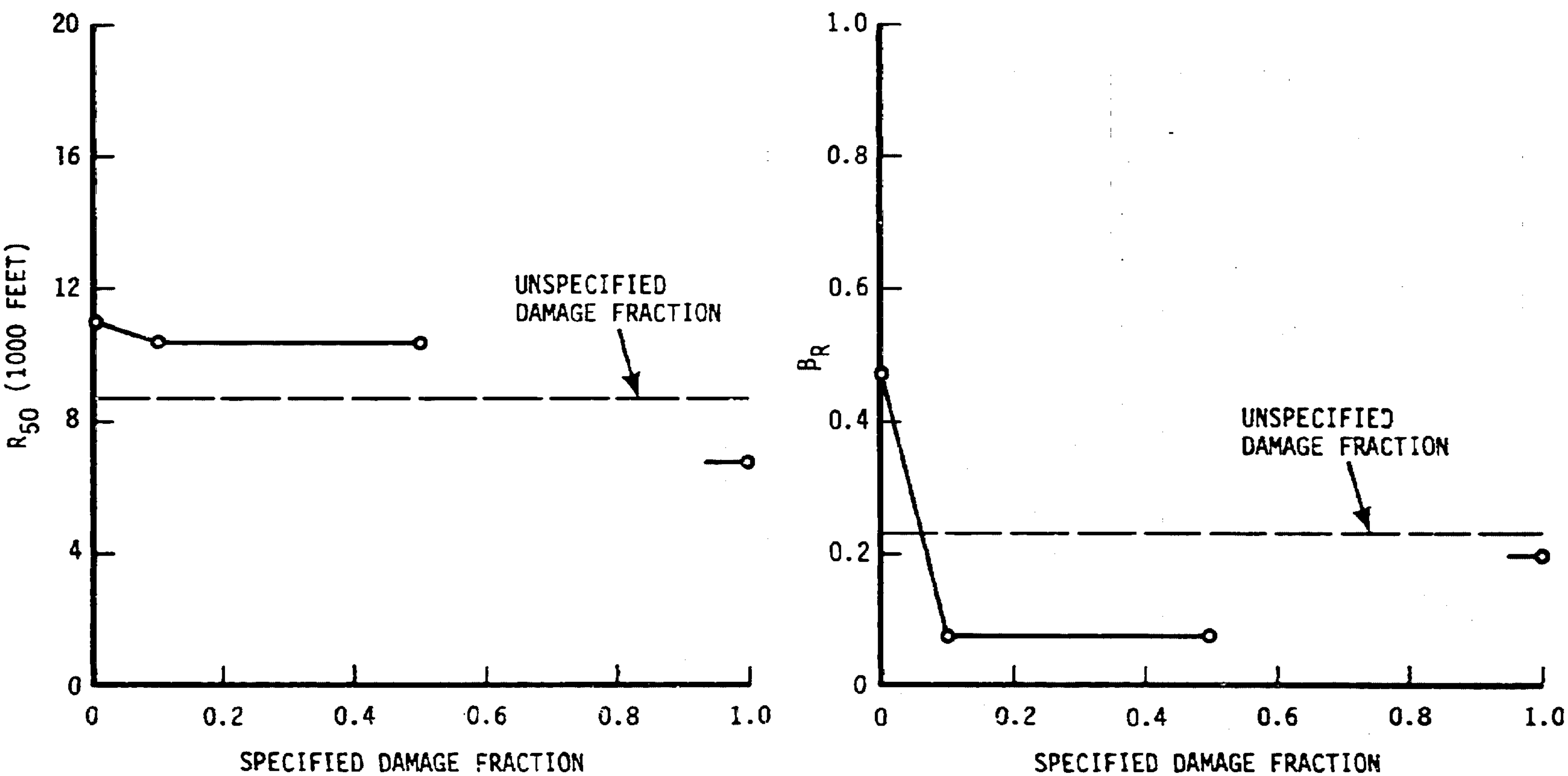
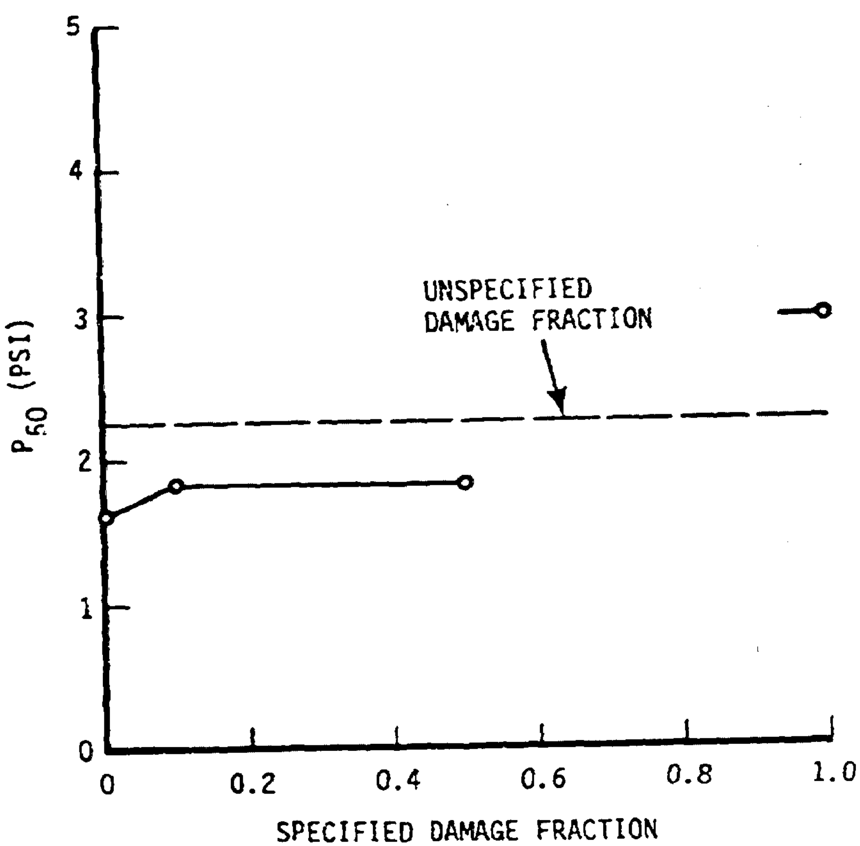


FIGURE 38e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

SINGLE-STORY STEEL FRAME BUILDINGS
WALL & ROOF COVER MATERIAL FAILS SLOWLY
SUPERFICIAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT



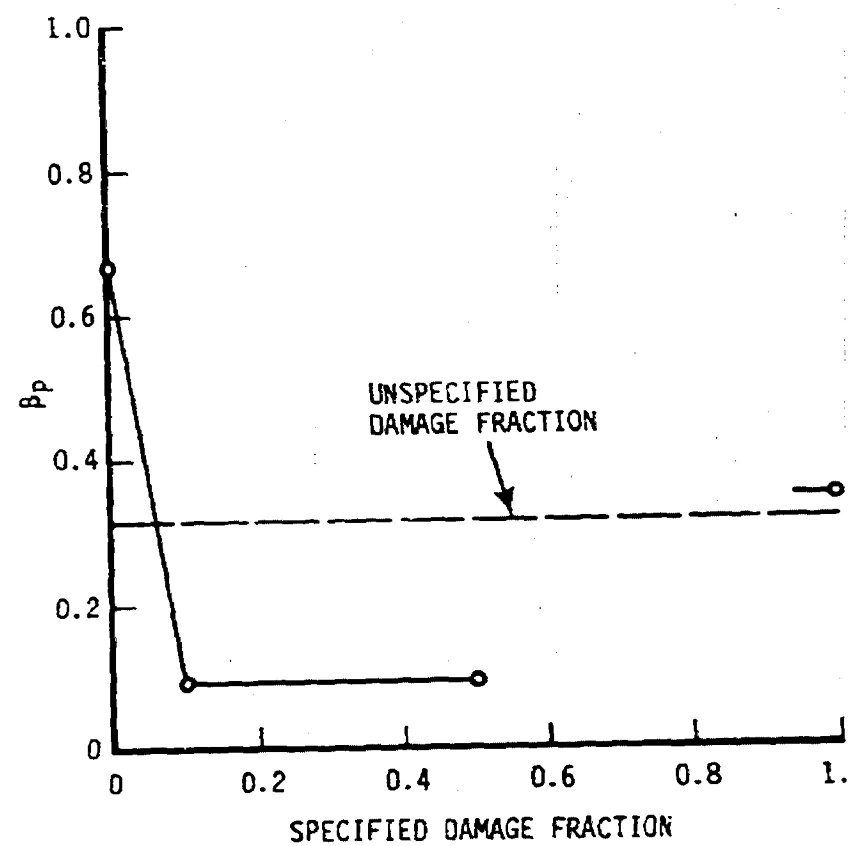


FIGURE 38f

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY STEEL FRAME BUILDINGS

WALL & ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

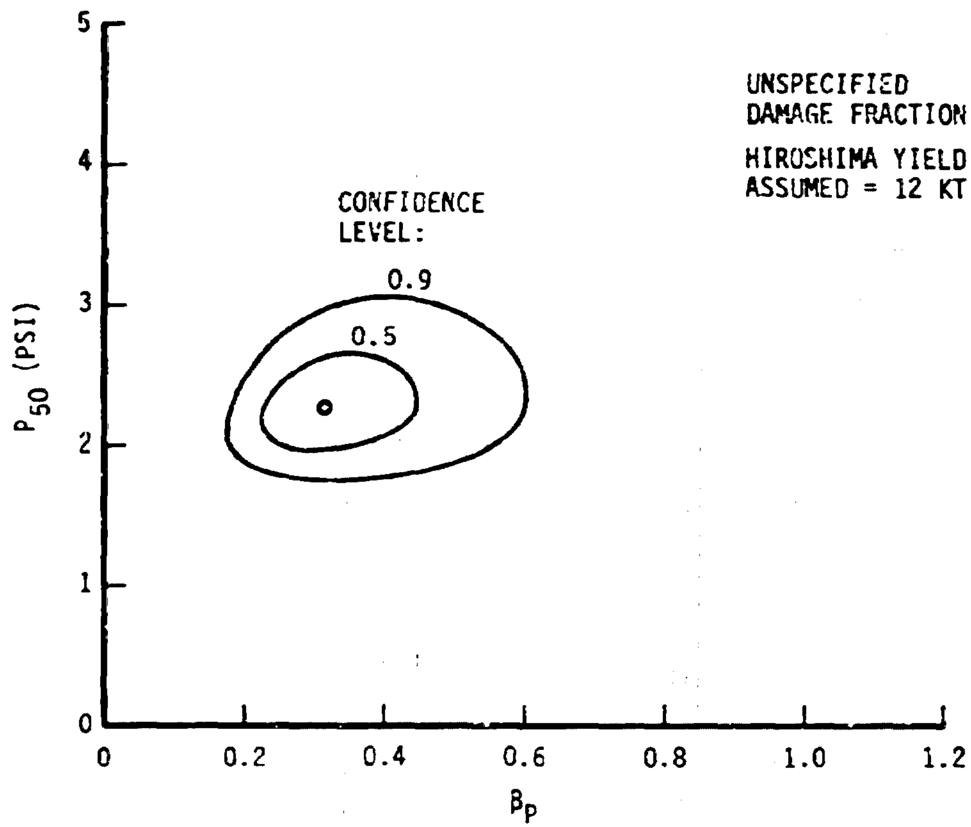


FIGURE 38g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY STEEL FRAME BUILDINGS AT HIROSHIMA

WALL & ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

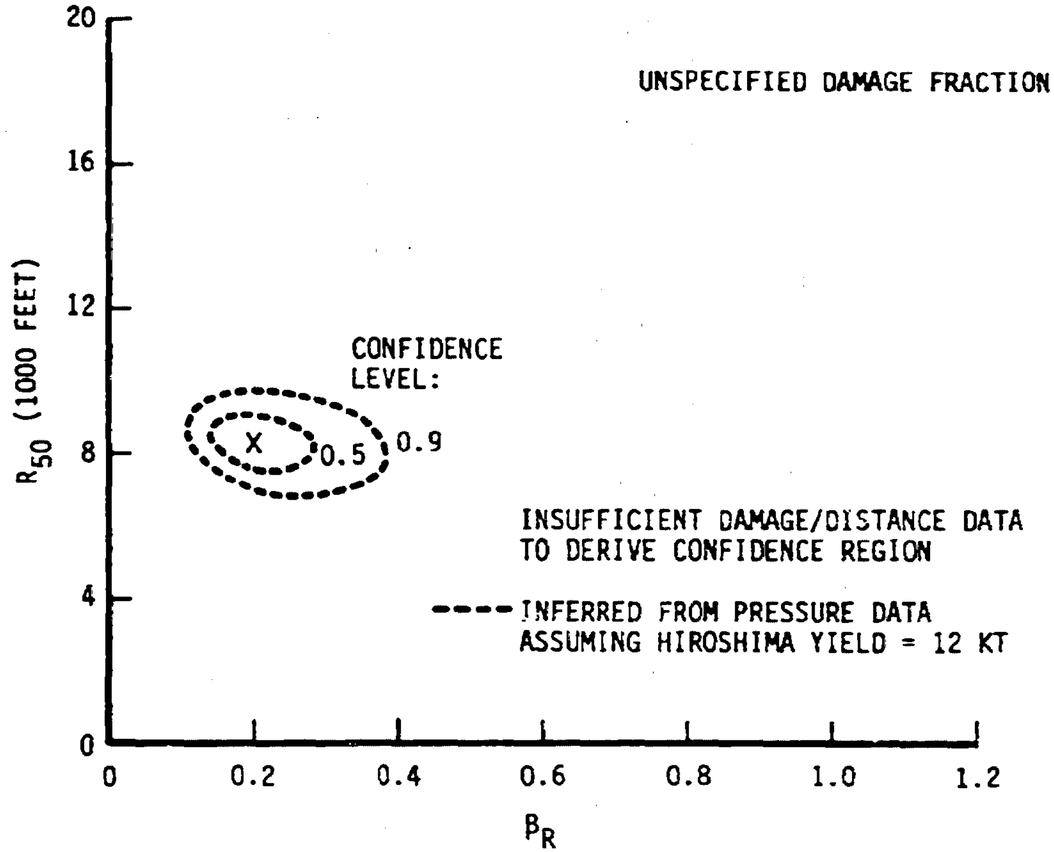


FIGURE 38h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY STEEL FRAME BUILDINGS AT NAGASAKI

WALL & ROOF COVER MATERIAL FAILS SLOWLY

SUPERFICIAL DAMAGE CRITERIA

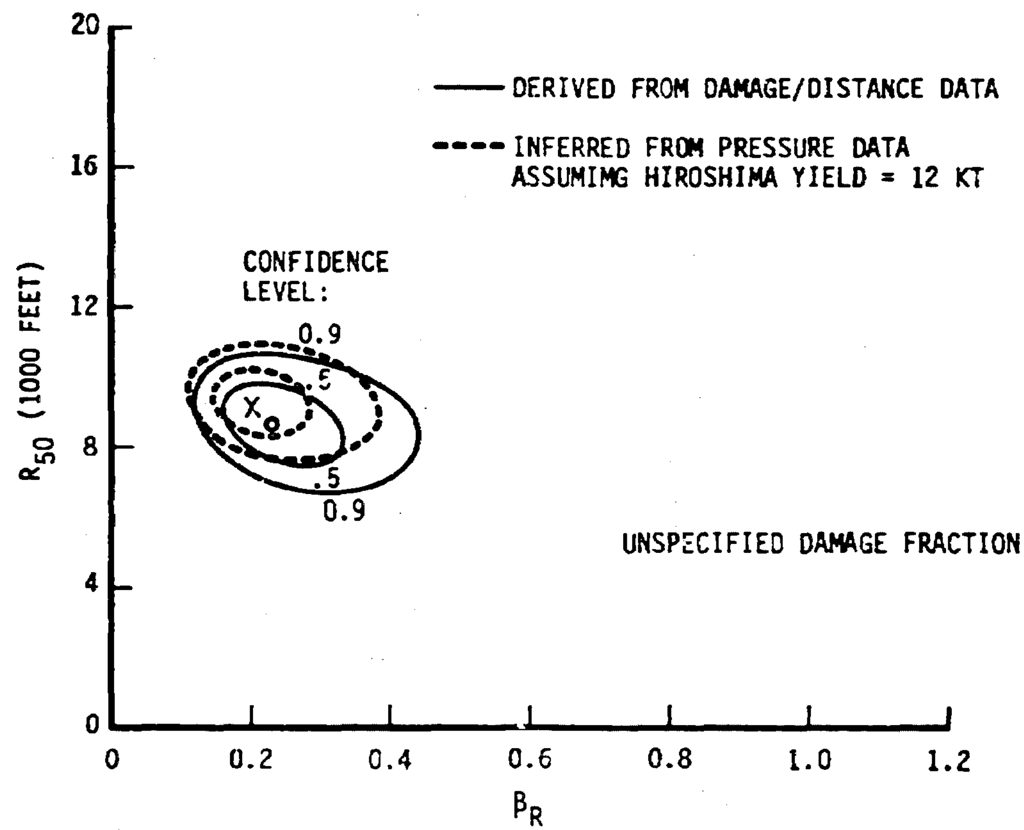


FIGURE 39a

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY STEEL FRAME BUILDINGS AT HIROSHIMA
WALL & ROOF COVER MATERIAL FAILS QUICKLY
SUPERFICIAL DAMAGE CRITERIA

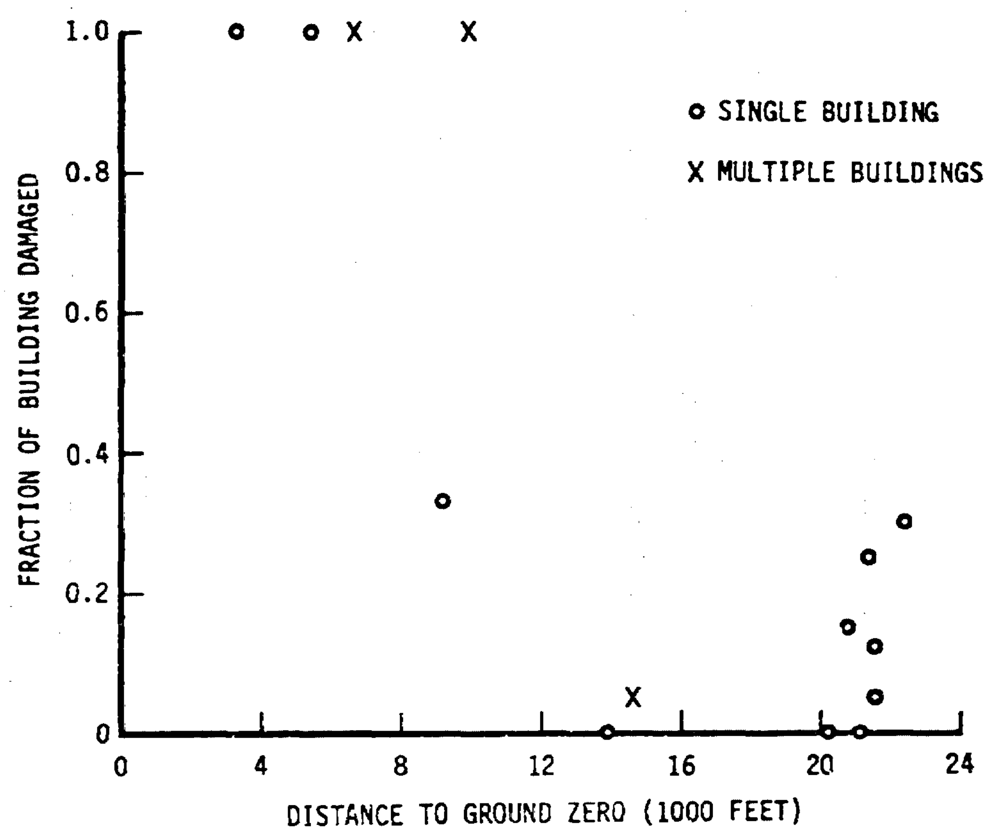


FIGURE 39b

DAMAGE VERSUS DISTANCE DATA

SINGLE-STORY STEEL FRAME BUILDINGS AT NAGASAKI
WALL & ROOF COVER MATERIAL FAILS QUICKLY
SUPERFICIAL DAMAGE CRITERIA

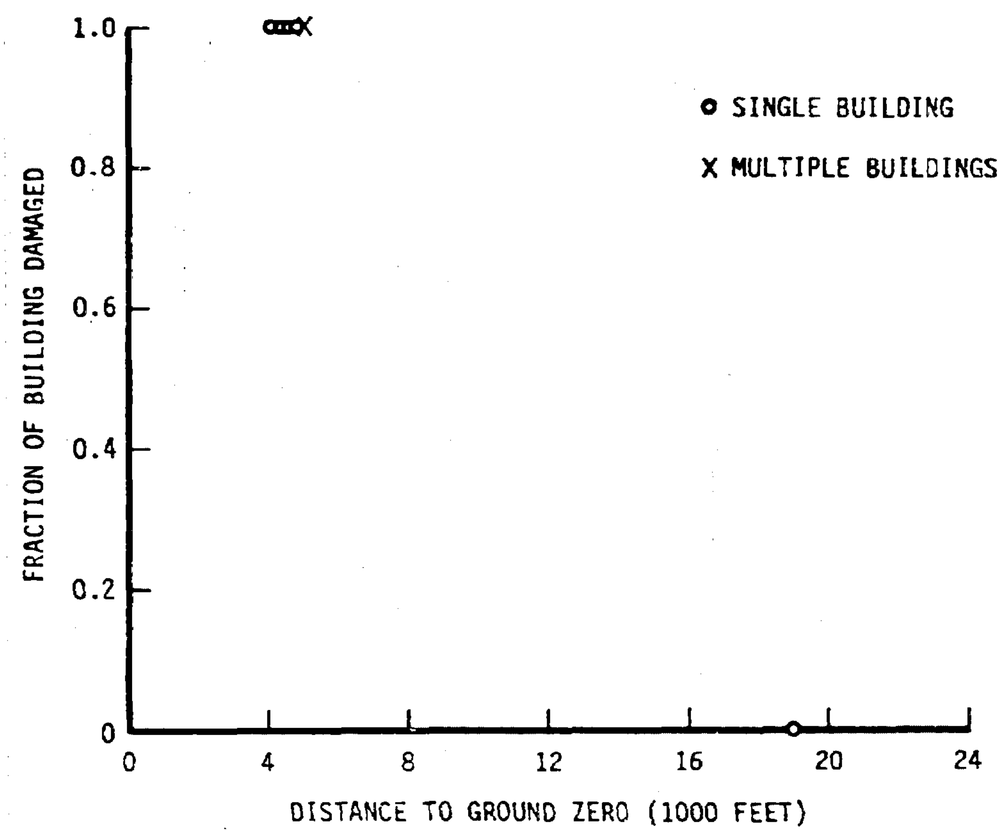


FIGURE 39c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY STEEL FRAME BUILDINGS AT HIROSHIMA

WALL & ROOF COVER MATERIAL FAILS QUICKLY

SUPERFICIAL DAMAGE CRITERIA

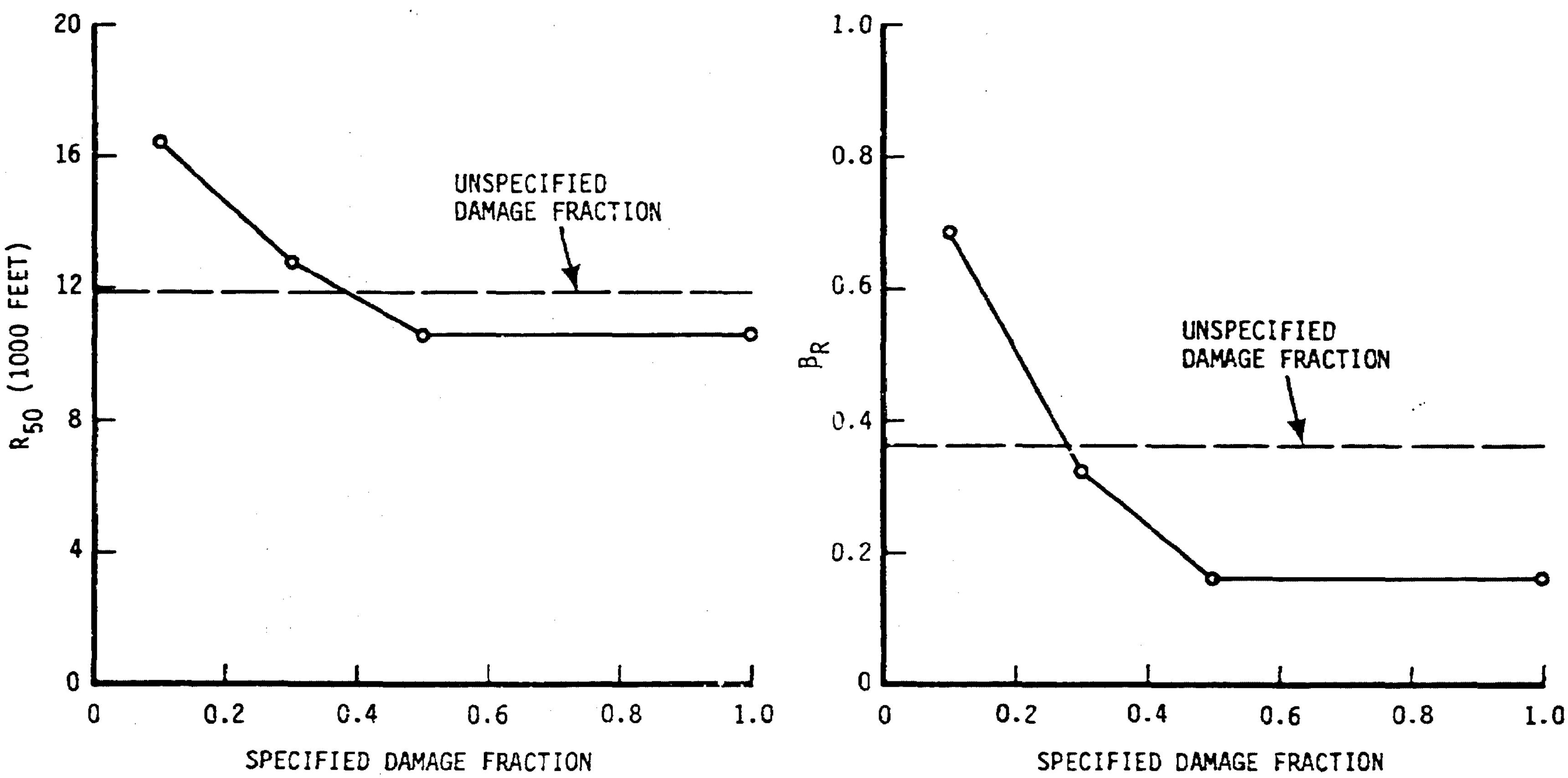


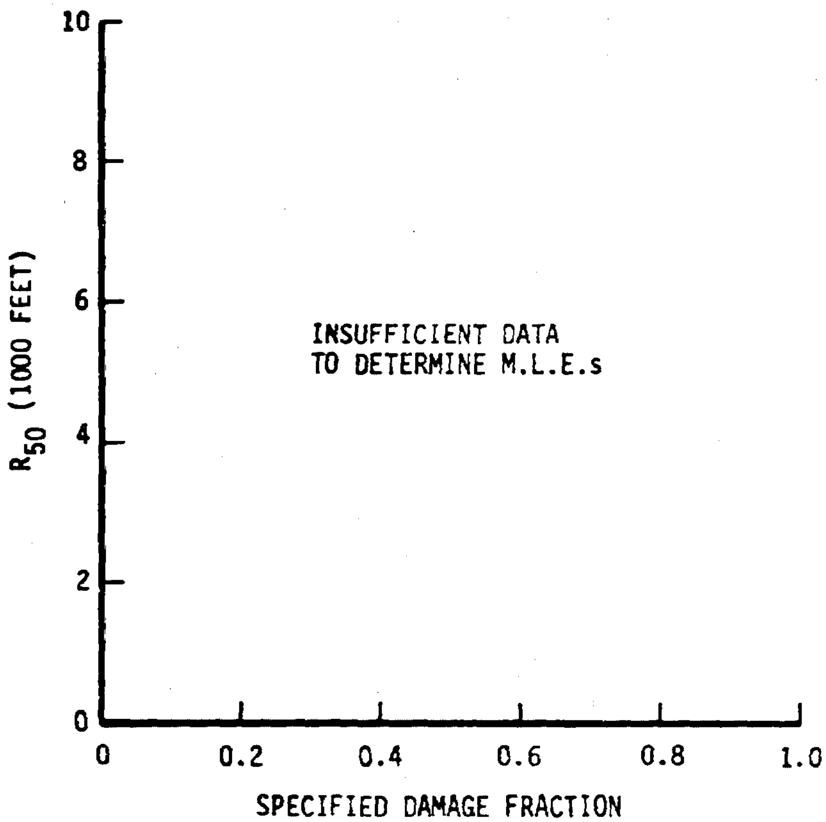
FIGURE 39d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

SINGLE-STORY STEEL FRAME BUILDINGS AT NAGASAKI

WALL & ROOF COVER MATERIAL FAILS QUICKLY

SUPERFICIAL DAMAGE CRITERIA



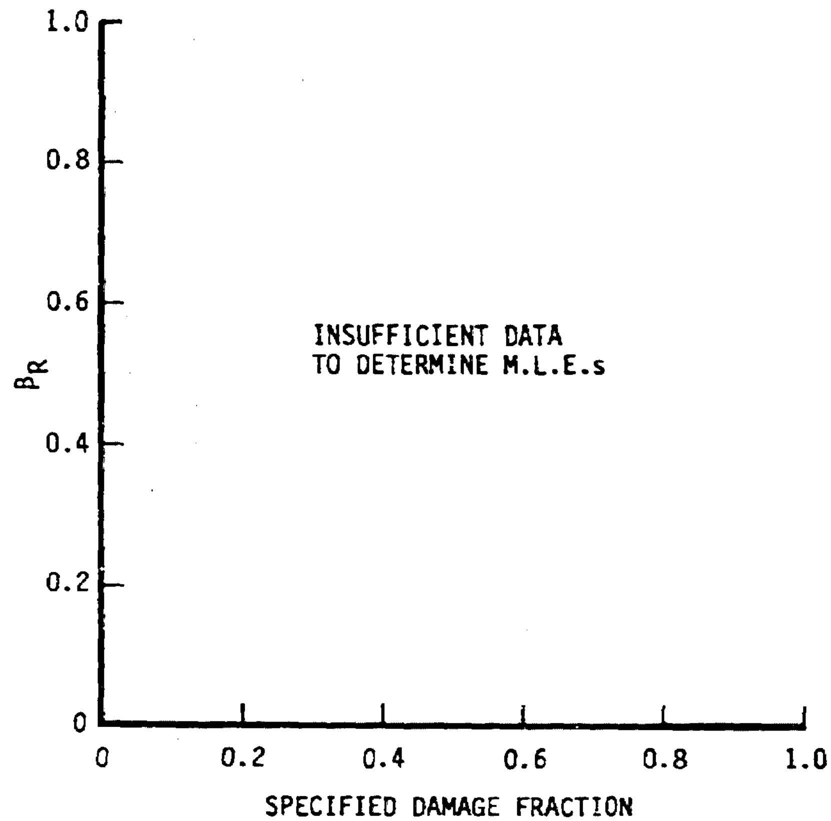
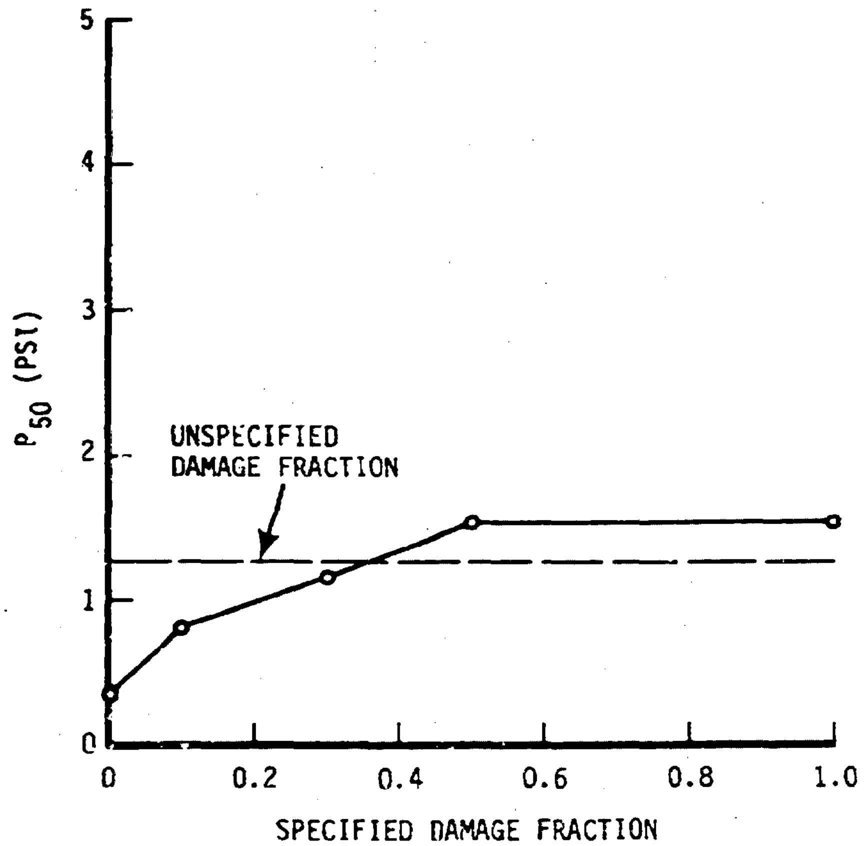


FIGURE 39e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

SINGLE-STORY STEEL FRAME BUILDINGS
WALL & ROOF COVER MATERIAL FAILS QUICKLY
SUPERFICIAL DAMAGE CRITERIA

HIROSHIMA YIELD ASSUMED = 12 KT



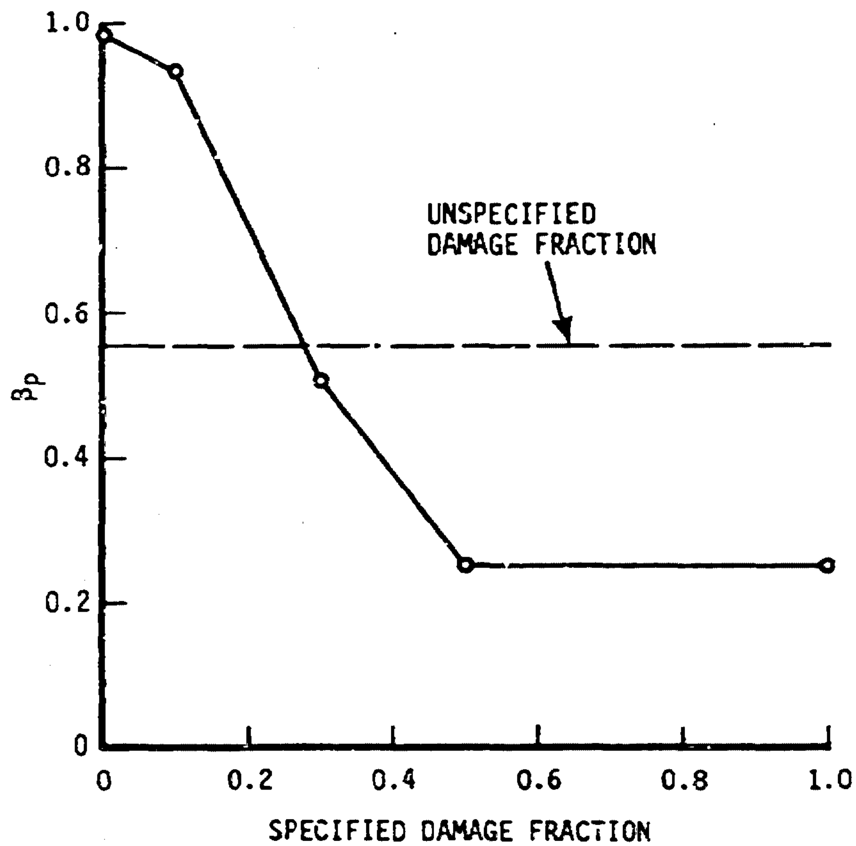


FIGURE 39f

CONFIDENCE REGIONS FOR P_{50} AND β_P

SINGLE-STORY STEEL FRAME BUILDINGS

WALL & ROOF COVER MATERIAL FAILS QUICKLY

SUPERFICIAL DAMAGE CRITERIA

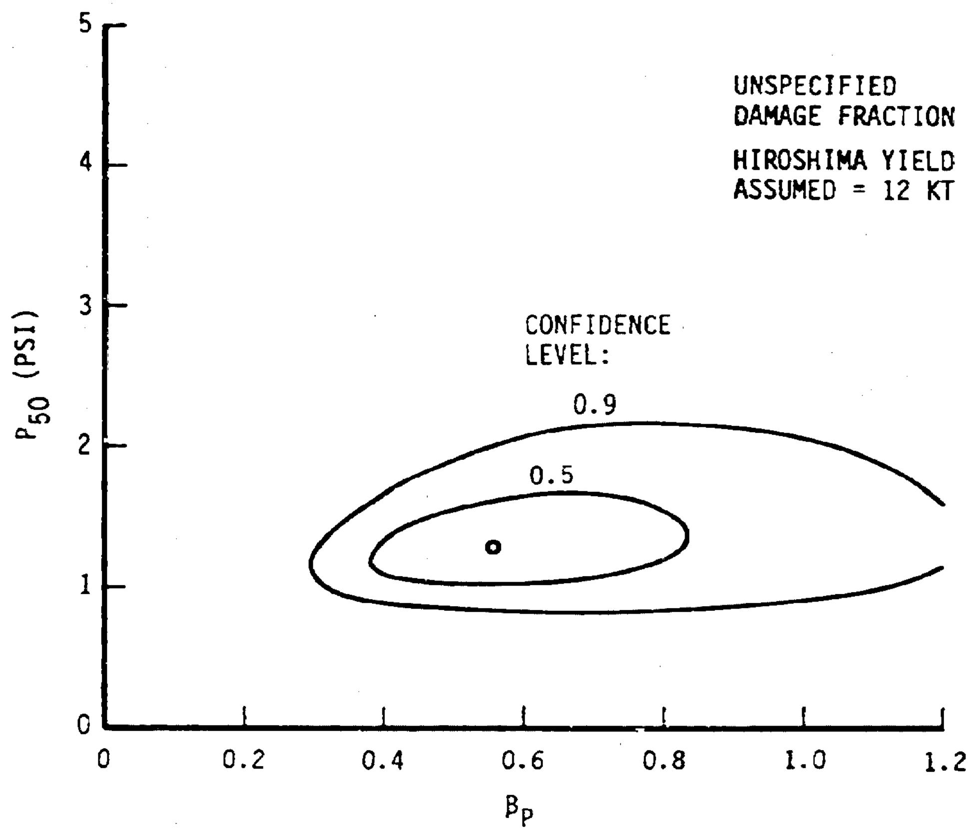


FIGURE 39g

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY STEEL FRAME BUILDINGS AT HIROSHIMA

WALL & ROOF COVER MATERIAL FAILS QUICKLY

SUPERFICIAL DAMAGE CRITERIA

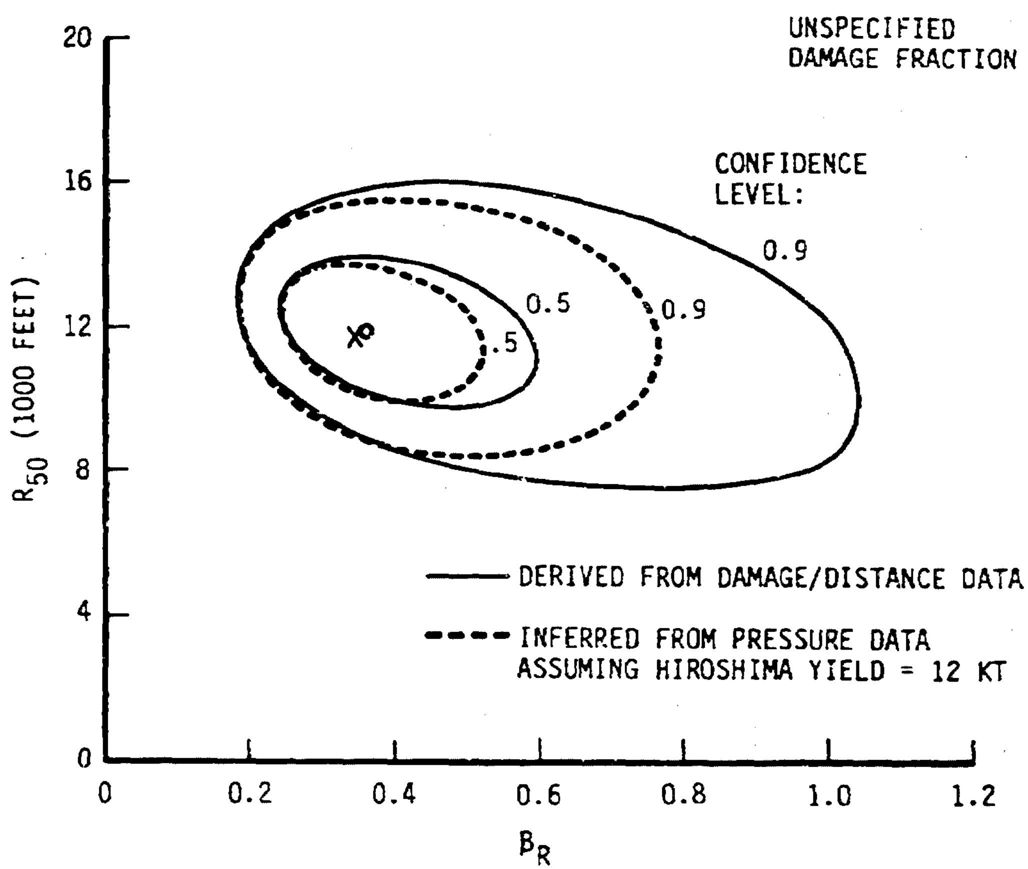


FIGURE 39h

CONFIDENCE REGIONS FOR R_{50} AND β_R

SINGLE-STORY STEEL FRAME BUILDINGS AT NAGASAKI
WALL & ROOF COVER MATERIAL FAILS QUICKLY
SUPERFICIAL DAMAGE CRITERIA

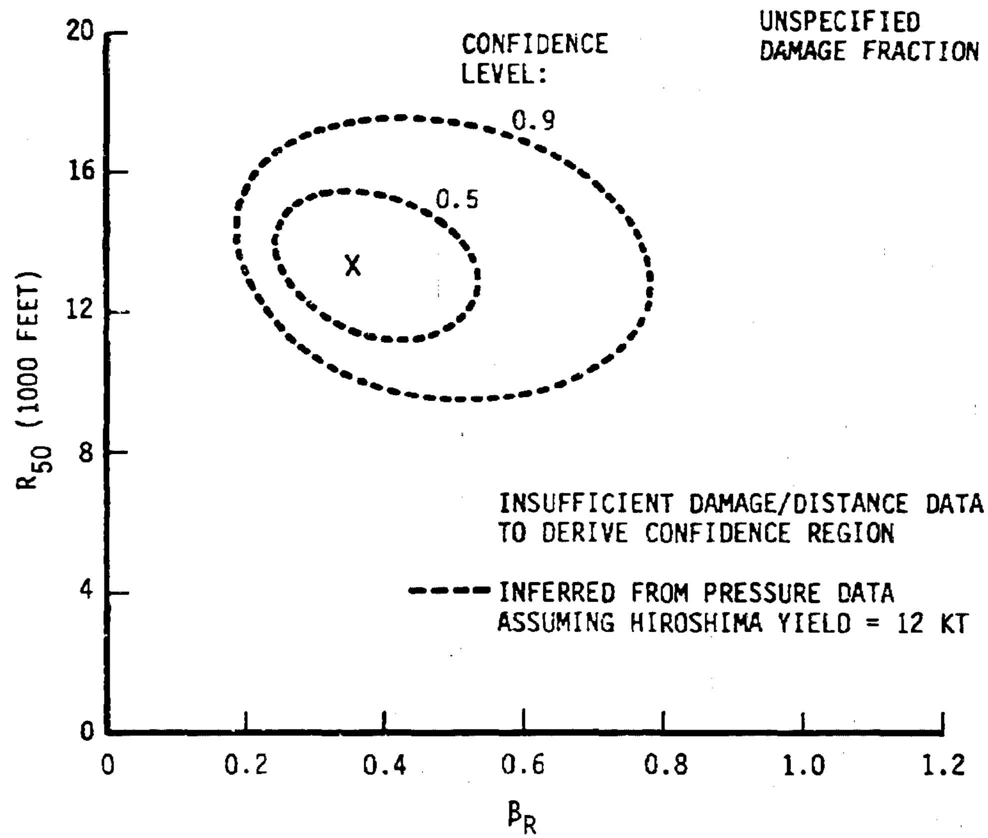


FIGURE 40a

DAMAGE VERSUS DISTANCE DATA

GLASS IN BUILDINGS AT HIROSHIMA
GLASS BREAKAGE

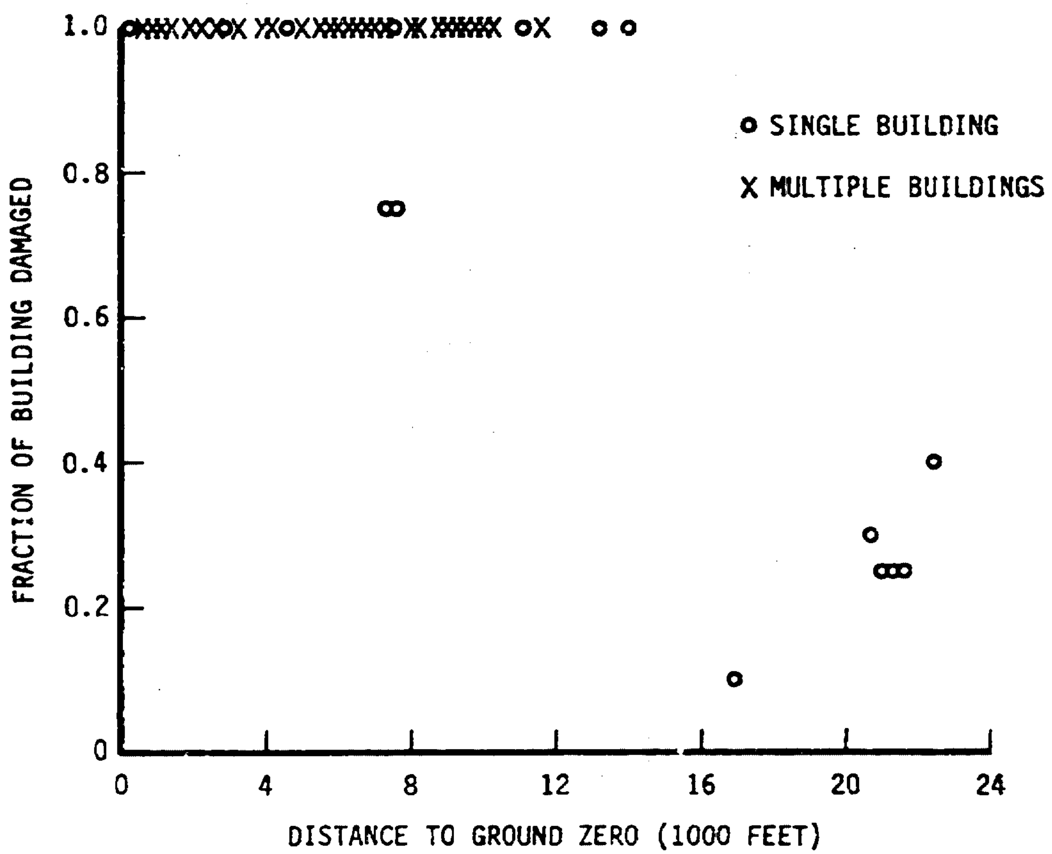


FIGURE 40b

DAMAGE VERSUS DISTANCE DATA

GLASS IN BUILDINGS AT NAGASAKI

GLASS BREAKAGE

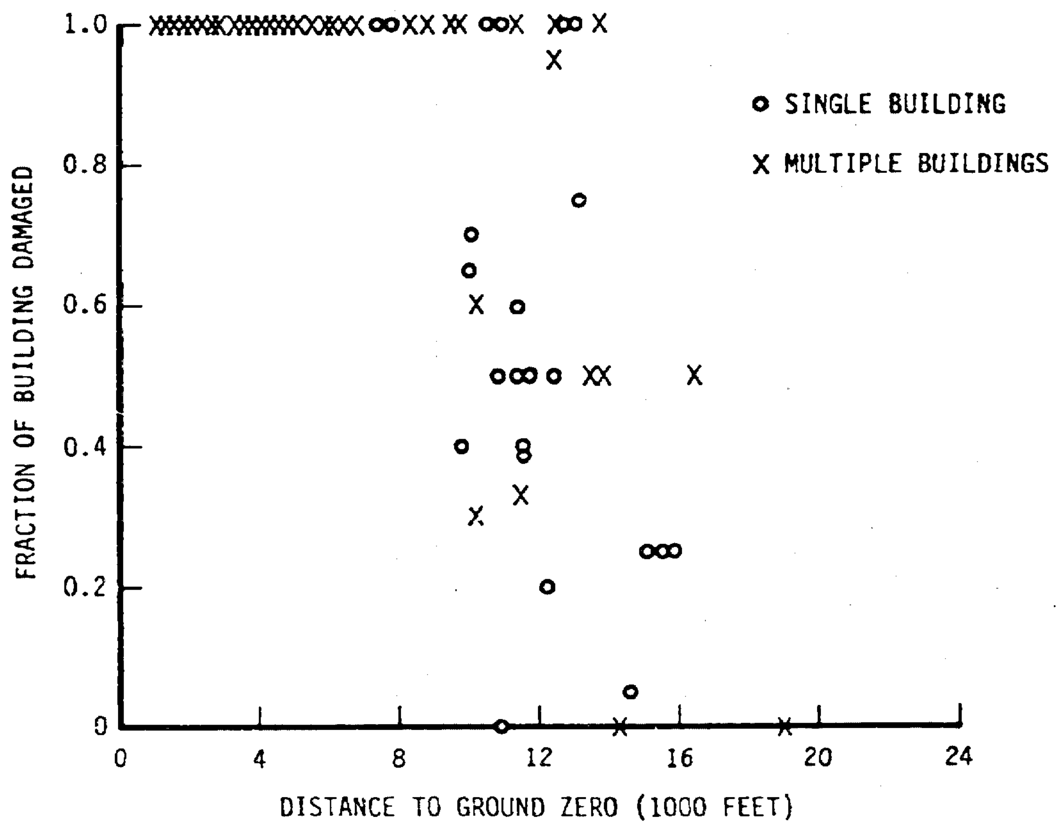


FIGURE 40c

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

GLASS IN BUILDINGS AT HIROSHIMA

GLASS BREAKAGE

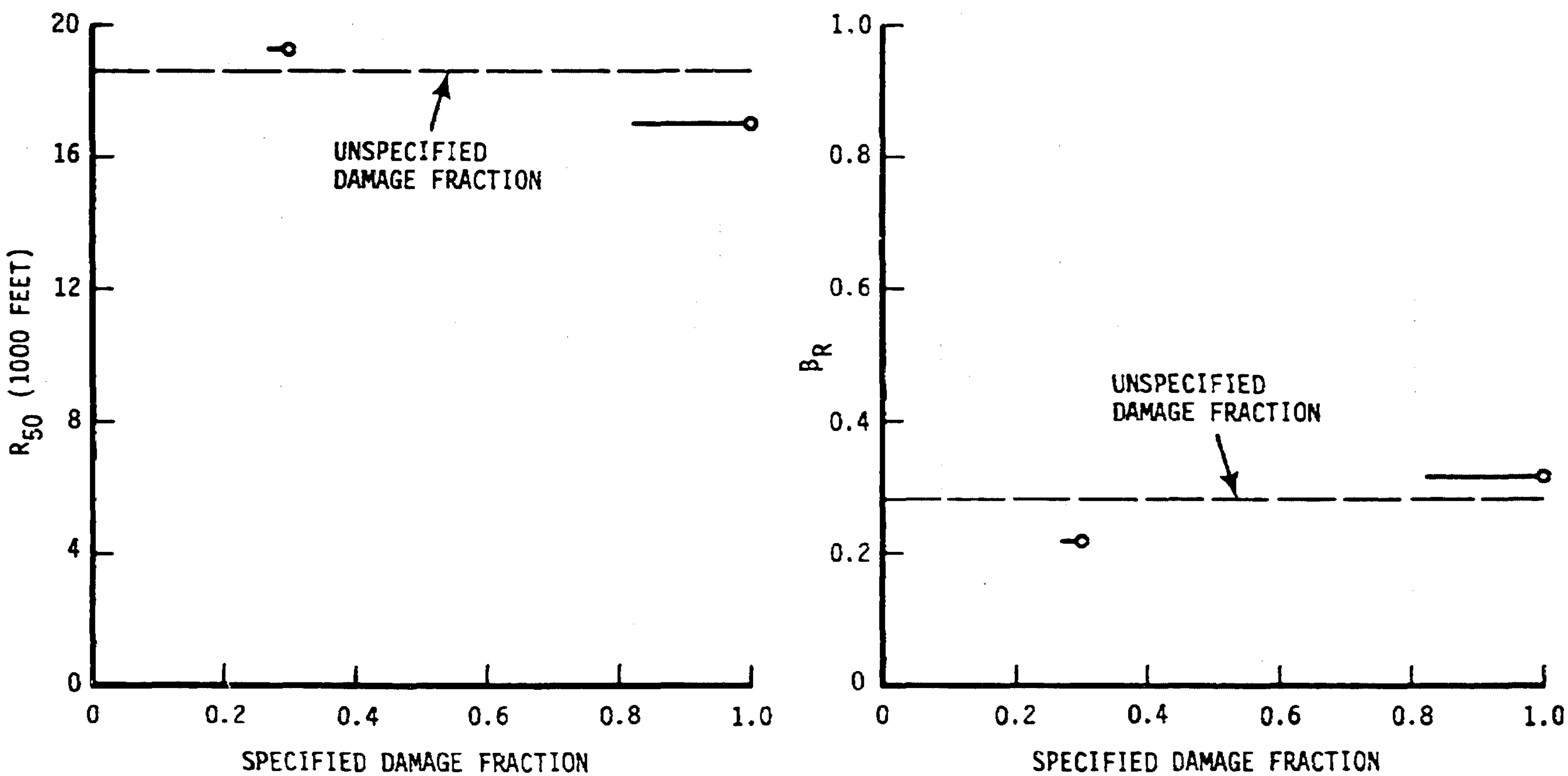


FIGURE 40d

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF R_{50} AND β_R

GLASS IN BUILDINGS AT NAGASAKI

GLASS BREAKAGE

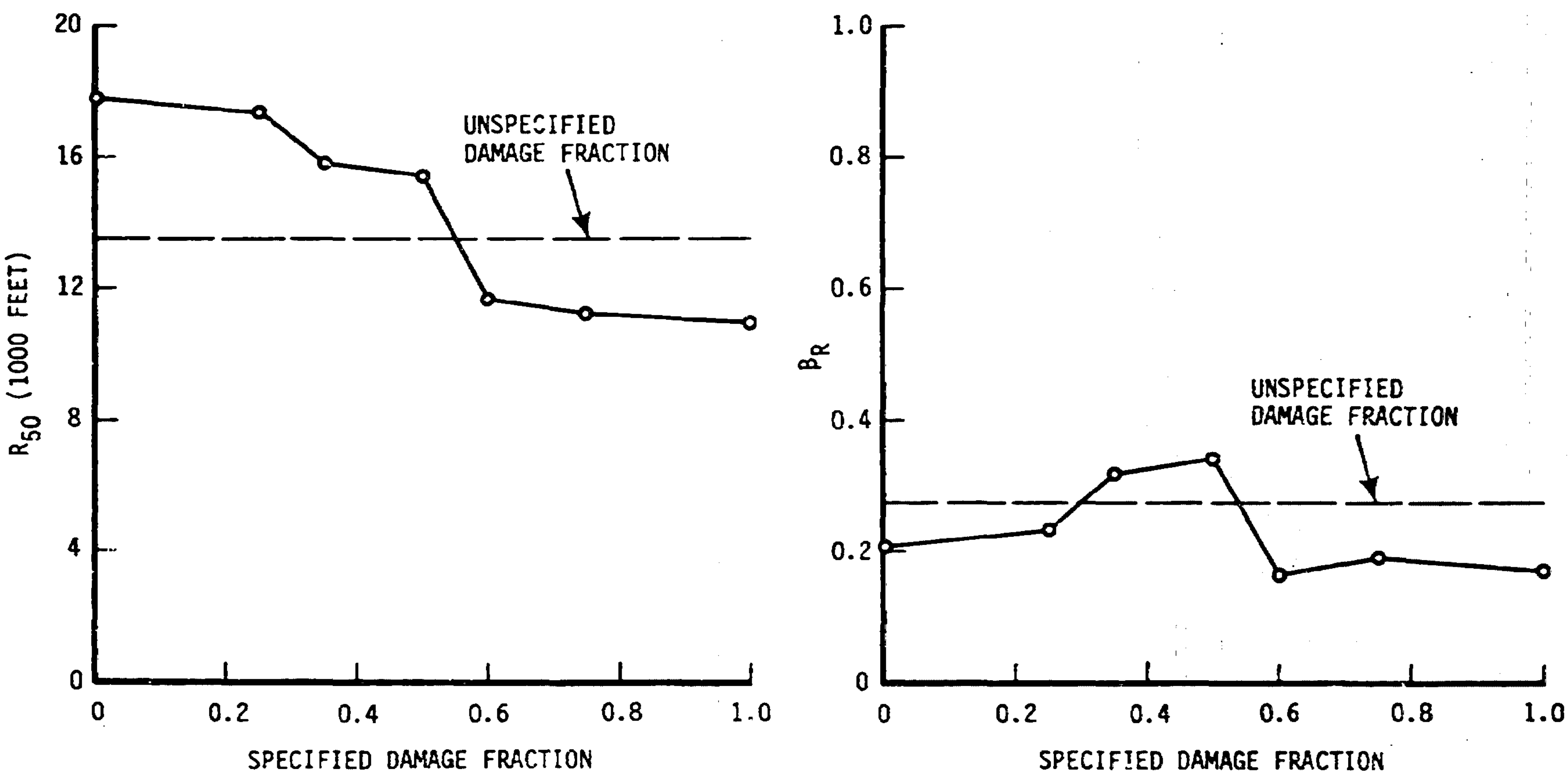


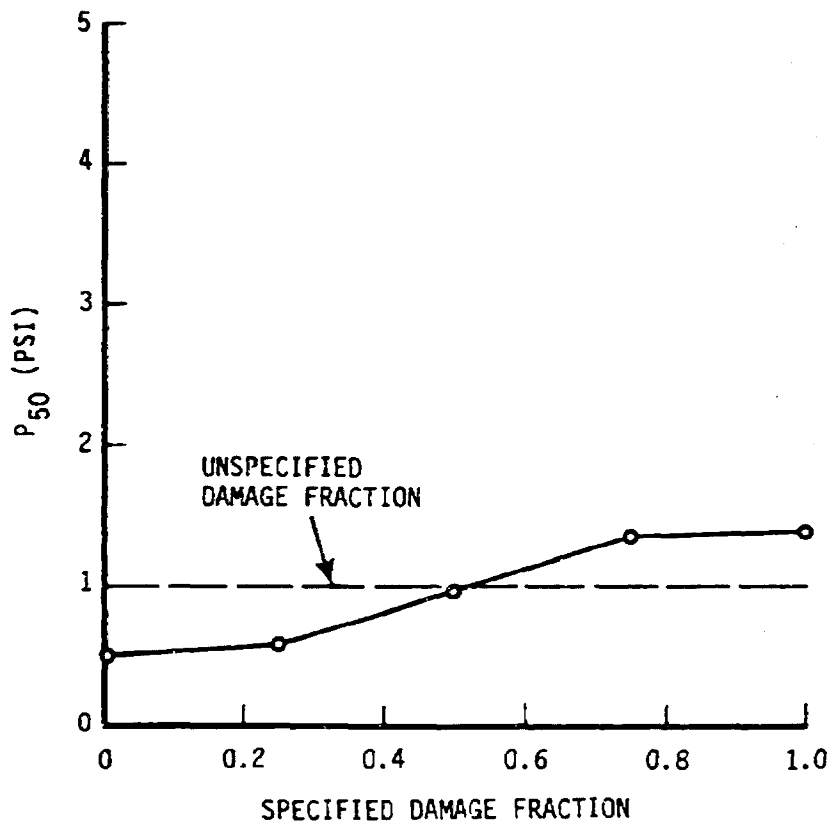
FIGURE 40e

EFFECT OF SPECIFIED DAMAGE FRACTION ON M.L.E. OF P_{50} AND β_P

GLASS IN BUILDINGS

GLASS BREAKAGE

HIROSHIMA YIELD ASSUMED = 12 KT



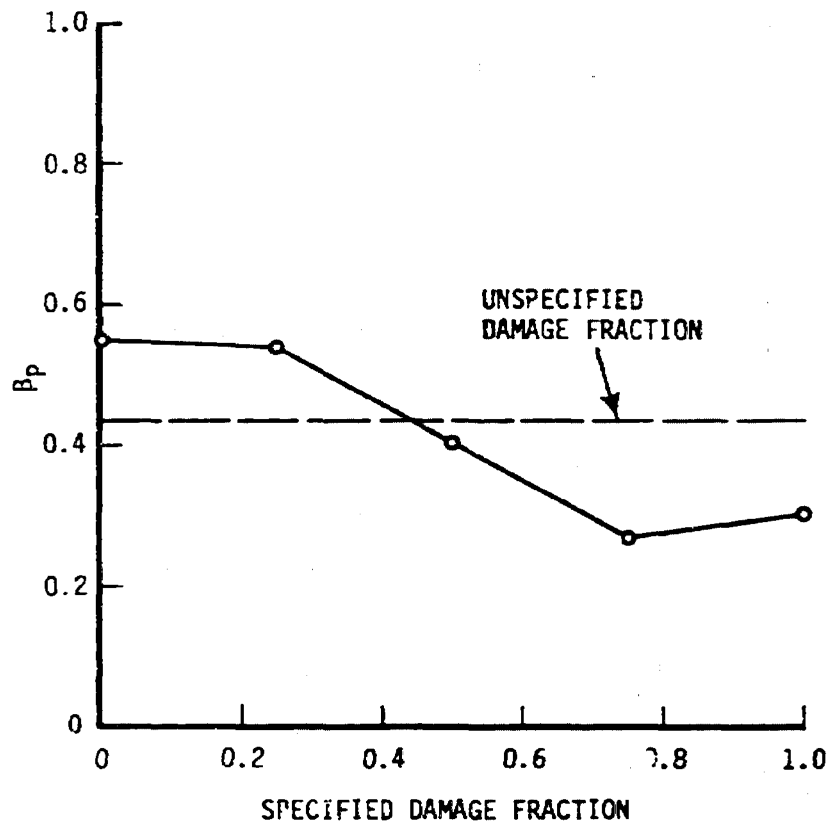


FIGURE 40f

CONFIDENCE REGIONS FOR P_{50} AND β_P

GLASS IN BUILDINGS

GLASS BREAKAGE

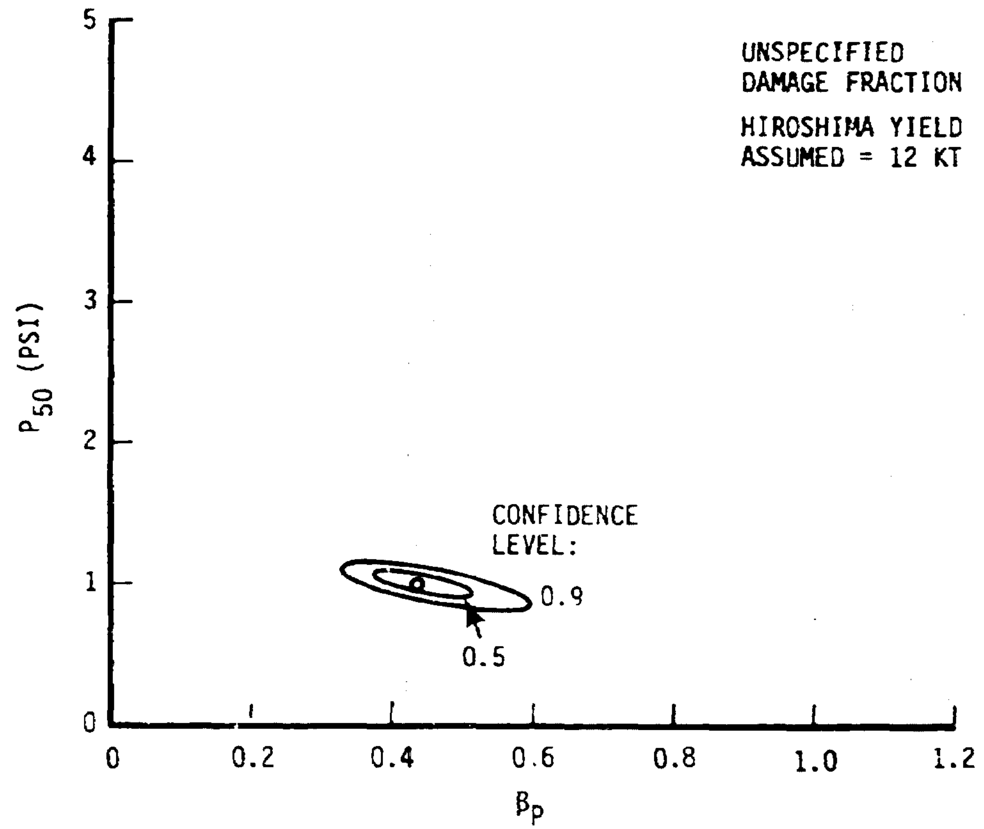


FIGURE 40g

CONFIDENCE REGIONS FOR R_{50} AND β_R

GLASS IN BUILDINGS AT HIROSHIMA

GLASS BREAKAGE

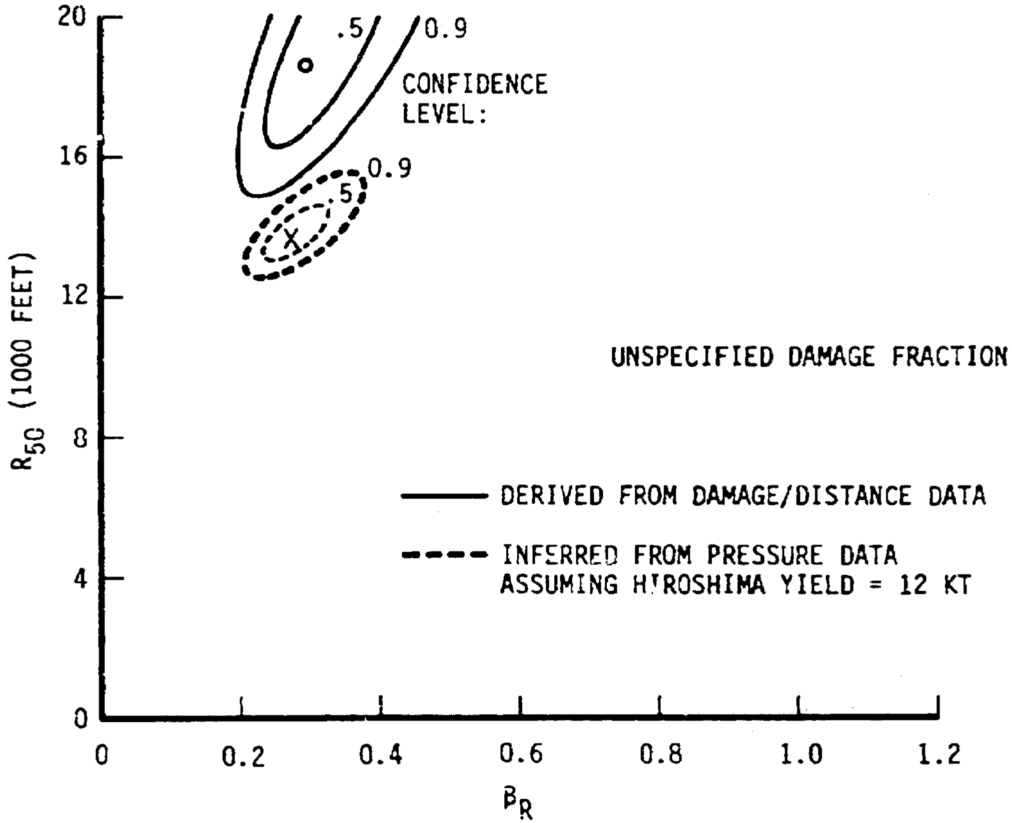
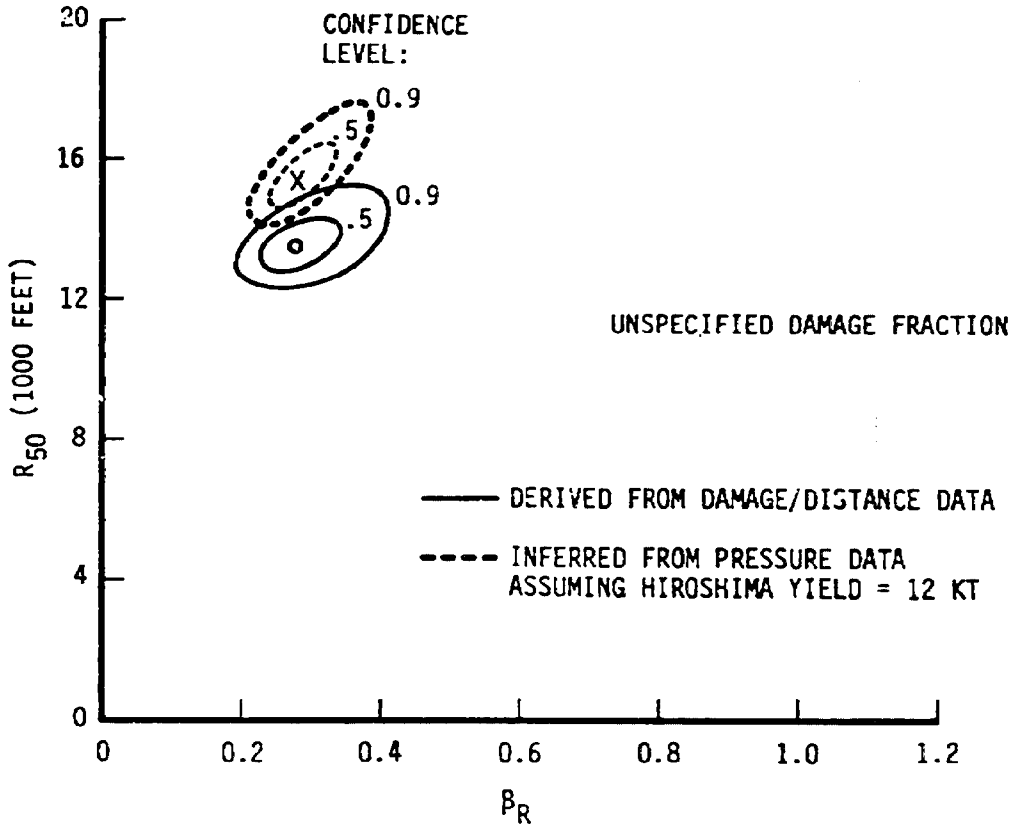


FIGURE 40h

CONFIDENCE REGIONS FOR R_{50} AND β_R

GLASS IN BUILDINGS AT NAGASAKI

GLASS BREAKAGE



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